

Planning Logging: Two Case Studies on the Queen Charlotte Islands, B.C.

by
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ABSTRACT

This report discusses the process of planning logging operations on steep, unstable terrain on the Queen Charlotte Islands, British Columbia. The report describes the current logging planning process, its data requirements and methods of data collection, and the results of a series of alternative logging plans prepared to minimize the potential for logging-accelerated mass wasting. Recommendations are also made for improving the planning process through the amount and quality of data required, evaluating alternative plans, and logging-system selection.

Intensive ground mapping on two watersheds provided data for the preparation of detailed logging plans. The logging plans involved various combinations of equipment, including equipment that was in common use at the time (highlead, mobile yarding crane, and grapple), equipment that was less common (tower skyline), and equipment not yet available (helicopter).

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1 INTRODUCTION

This report discusses the process of planning logging in natural forests. It specifically deals with forest development, the location of roads, and the layout of logging cutblocks in areas on the Queen Charlotte Islands that are subject to mass wasting. It is based on information collected from industry and agency reports, studies conducted by the Forest Engineering Research Institute of Canada (FERIC) on the Queen Charlotte Islands, and discussions with personnel actively involved with logging planning. Detailed field information about topography, soil, and timber was collected on two demonstration areas, and sample logging plans were evaluated to determine the potential of using alternative yarding systems to reduce landslides on logged areas.

The information presented here will assist industrial, environmental, and regulatory personnel to understand better the requirements of the planning process. It also provides logging planners with a methodology and checklist with which to analyze and review planning procedures.

This is the fourth in a series of reports prepared by FERIC for the Fish/Forestry Interaction Program (FFIP). In 1980, during the initial discussions with the Technical Advisory Committee (TAC) of FFIP, FERIC concluded that identifying sensitive forest sites and preparing good logging plans are essential if logging-accelerated mass wasting is to be reduced. To demonstrate the importance of site identification and planning, FERIC suggested that case-study plans be made of several areas that were scheduled for logging in the near future, thus enabling testing of a plan. Two areas located on the southwest side of Graham Island within the Phantom Creek and Hangover Creek drainages were suited to the study. Both were scheduled for logging; both contained difficult topography with sensitive sites; and both were large enough to accommodate a variety of logging systems, including skylines and helicopters.

This report presents the results of the planning exercise only. Because of declining economic conditions within the forest industry during the study period, the study sites were not logged. However, the field surveys undertaken provided detailed data for evaluation of several planning approaches, and FERIC was able to achieve most of its objectives.

The purpose of this report is to:

1. describe the current logging planning process, its data requirements, and methods of data collection;
2. prepare plans that use alternative logging methods, and to compare the results of these plans to those developed by the current process;
3. recommend improvements to the current logging-planning process, and to specify the amount and quality of data required for planning logging sites on steep, potentially sensitive terrain.

2 APPROACHES TO LOGGING-LAYOUT ON THE QUEEN CHARLOTTE ISLANDS

2.1 Historical Perspective

Until the 1970's, logging on the Queen Charlotte Islands took place primarily on stable, lower-elevation areas, and used the highlead system. At that time, planning staff were not aware of the consequences of logging the steeper slopes and it was not until landslides occurred that the seriousness of the problem was identified.

The prevention of mass wasting on the Queen Charlotte Islands is difficult. The area, which was recently glaciated, has a high level of natural instability, as well as very steep slopes, high rainfall, and strong winds. Roads must often be built across unstable areas to access merchantable timber on stable slopes. The timber resource itself contributes to the difficulty. The Sitka spruce trees are extremely large and tall (many 2 m in diameter and 70 m tall) and the logs are heavy (8 t). Felling tall trees on slopes requires room, and timber

edges must be protected to prevent damage from winds. These factors restrict the use of selective logging techniques and result in large clearcuts. Large, heavy equipment and wide roads are necessary to harvest and transport the logs. The low-quality understory and decadent over-mature trees in these forests produce a large volume of logging debris, some of which may accumulate in gullies and add to the volume of material in landslides.

The Queen Charlotte Islands are recognized as a unique area on the Pacific Coast, with special environmental features. Public attitudes about the Islands affect the logging planning process. Since the mid-1970's, agency and industry planners have introduced methods to identify critical sites and have been more selective in where and how to log these sites.

Forest engineers and others involved in the planning process now have experience in planning logging operations on terrain that is subject to slope failure. Many field layout people have worked actively with terrain specialists to develop acceptable logging plans, and hence have improved their own ability to match logging operations to the terrain. Specialists have also benefitted from working with industry and have become increasingly effective in proposing solutions to localized problems. In addition, companies have introduced new road-building techniques and logging methods. Companies now recognize the need to rehabilitate roads and landings after use. All these measures have helped to reduce logging-related mass wasting on the Queen Charlotte Islands. If the important timber resource remaining on steep slopes is to be fully used, however, industry and government must agree on the intensity of planning; and agencies must be assured that mass-wasting impacts on fish and the forest site will be limited to acceptable levels. Agency staff must also be assured that the plan adequately considers all the resource values and that protection measures are introduced where necessary.

Improving the planning process could further reduce logging-related landslides and help provide access to more timber.

2.2 Timber Resource

The timber on slopes classified as unstable but loggable can be important to the forest industry and to the province. The *Forest and Range Resource Analysis Report* (B.C. Ministry of Forests 1980) states "... operability problems are crucial to the [Queen Charlotte TSA] wood supply. Because of slope instability, most of the volume on the middle and upper slopes is not presently available." However, Lewis points out that, "the most productive Sitka spruce sites, which are among the most productive forest sites in the Province, are inextricably linked to active geomorphological [mass wasting] processes of erosion and deposition."¹

Most of the forest land on the Queen Charlotte Islands (Figure 1) is Crown owned. The land is managed by forest companies through Tree Farm Licenses (TFL's) and Timber Licenses, and by the Ministry of Forests through Timber Supply Areas (TSA's). Unstable forest land on the Queen Charlotte Islands has been identified and adjustments have been made to the annual allowable cuts. Before 1982, inventory data were general and annual-cut calculations assumed that all timbered areas, regardless of tree mix, quality, or accessibility, were harvestable. Today, 68 900 ha have been removed from the TSA as either Environmental Protection Areas (EPA's) or as Unstable, and this is 30% larger in area than productive forest (53 400 ha).

However, the MOF estimates that 10% of the timber volume in the EPA's on the TSA may be available for logging, provided logging methods that will not result in excessive environmental damage are used (Ministry of Forests 1982). This could represent a volume of 3.8 million m³ to the industry.

The controversy surrounding logging of mid-slope areas overshadows the fact that the majority of areas designated for cutting each year are stable.² Acquiring approvals for cutting these areas is a relatively straightforward procedure; however, generally more preparation work is required than for other areas on the British Columbia Coast.³

¹ Lewis, T. 1979. The ecosystems of Lyall Island, Queen Charlotte Islands, B.C. Unpubl. report prepared for Western Forest Products, Ltd., Vancouver, B.C.

² R. Hanson, B.C. Min. of For., pers. comm., 1983.

³ J. Ronyecz, Western Forest Products Ltd., and D. Hoffman, Fletcher Challenge Canada Limited, pers. comm., 1983.

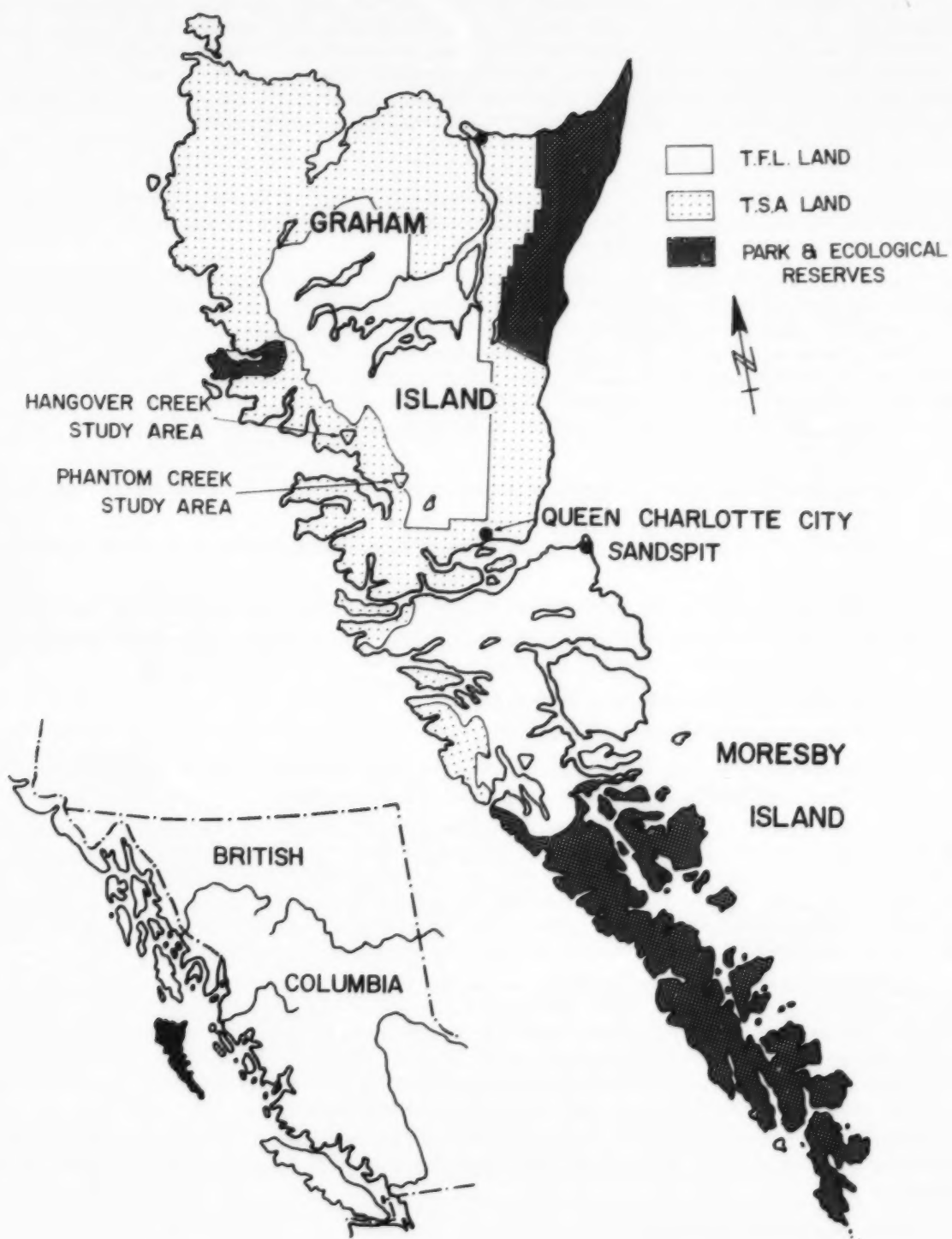


FIGURE 1: Queen Charlotte Islands study sites.

It is important to note that not all the area in the EPA's is unsuitable for logging. Many withdrawals of land were made as a result of agency and industry reaction to logging and fisheries confrontations. These withdrawals could include areas of "stable" land. In addition, some of the best timber stands occur on or around unstable areas and are often included within the withdrawn areas (Townshend 1981). Without this high-value timber to balance logging costs, it may be uneconomical to log adjacent timber areas of marginal value which occur on stable ground; or, the withdrawn areas may block access to the high-value timber.

2.3 Levels of Current Planning

"Planning is the process of analyzing and evaluating the implications of potential future actions, followed by the selection of a plan that can best realize desired goals. Planning is best summarized as the process of forethought and strategy selection" (Montgomery 1976).

During planning, it is essential to distinguish clearly between areas of temporary timber deferment and permanent withdrawal. Current plans are made and roads are constructed to harvest specific blocks of timber. If at some later date deferred timber is released for cutting, these roads may be in the wrong place for harvesting; therefore, it may be necessary to construct extra roads when logging restarts. Some of the present environmental problems on the Queen Charlotte Islands were caused by a lack of overall or total-chance planning. That is, individual cutblocks within large areas or watersheds were planned without reference to the future cutting of the adjacent timber. In addition, changing timber values and demand resulted in changing plans.

Planning, by definition, needs to be logical and systematic. Based on FERIC's experience, there are six basic steps to any logging planning process:

1. Defining the problem. How can an area be logged in a cost-effective and environmentally satisfactory way?
2. Analyzing the problem. Set the objectives and the minimum goals and conditions that must be met.
3. Developing several solutions. These must fully satisfy the objectives before attention is given to compromises, adaptations, and concessions.
4. Estimating costs and deciding on the best solution.
5. Converting the decision to effective action.
6. Reviewing the plan. This is done after the plan is in place so that feedback can be received on the validity and effectiveness of the plan compared to the actual results.

Planning is carried out at various levels — from the overall management unit to the very site-specific operational planning of a specific setting or group of settings (Toews and Brownlee 1981; Breadon 1983). To ensure that timber is removed in an economical and environmentally sound manner, planning forest-harvesting operations requires the collection of data, analysis of terrain conditions, and selection of the best options for road and yarding layout superimposed on terrain conditions. The information is presented on a map illustrating proposed road networks, yarding systems, and areas of site sensitivity.

In British Columbia, a referral system is used to process logging plans. This system is a process by which the Department of Fisheries and Oceans (DFO) and the Ministry of Environment (MOE) can input data and express concern to the Ministry of Forests. However, the ultimate responsibility for forest management and cutting permission resides with the Ministry of Forests. The DFO, through the federal *Fisheries Act*, can enact measures that prohibit any person from undertaking an action that may destroy fish or fish habitat. This is a powerful administrative tool that can be used to influence the final logging plan.

Table 1 shows the five levels of planning for TSA's and the four levels for TFL's undertaken in British Columbia. Planning begins at a broad level and progresses through to detailed layouts for specific cutting areas.

2.3.1 Broad-level planning

Management Working Plans prepared for all TSA's and TFL areas are long-term plans that balance the demands for timber to the supply available. In the past, they often lacked detail concerning accessibility and economics.

TABLE 1. Levels of planning on the Queen Charlotte Islands

Tenure	Plan	Purposes	Who prepares	Period	Area of concern
TSA only	1. Timber Supply Area (TSA)	Overall goals, strategies, and policies.	MOF Regional and District offices ^a	Long-term	Entire TSA
TFL and TSA	2. Management and Working Plans	Explains how the TFL and TSA objectives will be addressed.	Forest company staff	Long-term	The area of land a forest operator manages.
	3. Operability	Long-term operational development combined with terrain stability analysis.	TFL's: Forest company staff. TSA: Forest company staff plus MOF.	10-20 years	The overall area of forest land an operator expects to log within the 10- to 20-year period.
	4. Development Plan (5-Year Plan)	Operational measures to develop and log the next 5 years of timber.	Forest company staff	5 years	Specific areas to be logged within the next 5 years.
	5. Cutting Permits	Detailed operational specifications	Forest company staff	1-2 years	Specific logging areas.

^a Quota holders on the Queen Charlotte TSA review the proposed plan, whereas in other coastal areas quota holders actively participate in the preparation of plans. A quota holder is a company or individual having the right to harvest timber from the TSA.

The Queen Charlotte Islands' Forest District was the first area in British Columbia to use operability plans which integrate long-term logging development plans with terrain-stability mapping. The operability plan is prepared by industry forest engineers using terrain-stability and topographic maps, aerial photographs, and field reconnaissance data. Preparing operability plans ensures that areas which require special systems and consideration are identified before any adjacent development occurs. It is at this time that agencies can incorporate specific caveats on how development affects fish habitat, water quality, wildlife habitat, and scheduling.

2.3.2 Logging operations planning

The following discussion refers to the planning process followed by industry during this study period, i.e. 1981 to 1984.

Development plans, or five-year plans, are comprehensive operational plans. They state where and when a company proposes to operate. The road network and logging areas are identified on 1:20 000 topographic maps. The Ministry of Forests refers copies of the final plans to the MOE and DFO to review. Only areas approved on a development plan can progress to the cutting permit stage. Agency staff use the plan in their site assessment and inventory work.

A cutting permit must be obtained before a road can be constructed or timber felled. A separate road permit may be obtained if only authorization for road construction is required. The cutting permit is a detailed operation plan for all the roads and setting boundaries required within the permit area and is valid for a 1- to 3-year period. Before a permit is issued, all roads and boundaries must be marked in the field and any special measures required (such as stream protection) must be noted on 1:5000 topographic maps. In addition, a timber cruise must be completed to provide data required for calculation of stumpage rates.

The Ministry of Forests refers cutting permit applications to the MOE and DFO for review and comments. The review period can last up to 3 months, during which time field visits and discussions take place.

If agreement cannot be reached at the local level, issues may be raised to successive administrative levels within the agencies and companies.

2.3.3 Comments on the planning process

During the study, individuals within logging companies and agencies commented on the current planning process. They generally agreed that the process works well for most areas, but that there are problems when difficult areas are planned. The following is a list of the most common comments by group.

Industry representatives

- The detailed information that is necessary for planning logging operations on sensitive ground may eventually be required from all areas (including non-sensitive terrain).
- Terrain and stability mapping may be used to reject logging plans without there being adequate field review.
- Detailed feedback from agencies may be unavailable or received too late to be incorporated in the initial development.
- The required engineering layout is too detailed, and results in plans that lack flexibility. By the time additional information becomes available from road construction or as the cutting areas are developed, the plans are difficult to change.

Ministry of Forests

- Long-term planning (i.e., 20 years or more) that balances cutting areas for timber quality and accessibility is lacking.
- Information submitted in cutting permit applications lacks detail.

Ministry of Environment and Department of Fisheries and Oceans

- Industry plans are too general and have been changed without consultation after agency staff have undertaken detailed assessments.
- Submitted plans may not be realistic and cannot be carried out by the company or contractor.

These comments indicate that the planning process itself may not provide sufficient flexibility when difficult sensitive sites are involved. All participants in the planning process want detailed information from the other participants, but are reluctant to commit themselves in case new information becomes available during the progress of the work.

The time required for planning and pre-logging development is given in Table 2.

Delays that may increase the time between planning and the beginning of yarding are:

1. Cutting permits that are not approved by the Ministry of Forests and referred back to the company for changes.
2. Agency staff who do not have time to process applications or participate in field inspections.
3. Weather restrictions, such as summer dry period (fire hazard) and fall and winter rain storms, which can prevent road construction or falling.
4. The presence of fish in watercourses which may restrict road construction activities to specific times of the year.

TABLE 2. Planning and development: Time required^a

Phase	Minimum (months)	Maximum (months)
Planning phase		
Layout, field work, and office	3	6+
Development plan preparation and approval	6	12+
Cutting permit application preparation, timber cruise, and approval	6	6+
Development phase		
Road construction	2	6+
Falling	1	6+
Total	18^b	36+^b

^a This table refers to approval of 2- to 3-year development plan/cutting permits for a TFL and not for individual blocks within a licence area. In some cases, individual blocks may be engineered, a cutting permit approved, and a road constructed within 6 months.

^b Plus time for amendments.

3 INFORMATION REQUIRED TO PREPARE LOGGING PLANS

FERIC reviewed sources and types of information currently used for logging planning, and experimented with the quantity and quality of some additional basic information. It also examined some planning data that researchers have suggested would aid in planning logging operations on sensitive terrain. This section discusses the results of the information review. Table 3 summarizes the basic information that was available before FERIC's field work.

TABLE 3. Information available before the study

PHANTOM				HANGOVER				
	Date	Scale	Source ^a	Type of Information	Date	Scale	Source	Type of Information
Aerial photography	1977	1:15 000	MOEP (MB)	Black & white photographs	1978 1981 1981	1:15 000 1:10 000 1:10 000	MOEP (CIPA) FFIP FFIP	Black & white photographs Black & white photographs Colour photographs
Geological mapping	1968	1:250 000 500-ft contours	(^c)	Rock formations and rock types	1968	1:250 000 500-ft contours	(^b) and (^c)	
Surficial geology	1978	1:20 000	MB	Terrain classification	1979	1:20 000	4*	Geotechnic inventory Rennell Sound
Topographic mapping		1:5 000 (1:400 ft) 25-ft contours	MB	Topography & timber cover		1:5 000 (1:400 ft) 25-ft contours	CIPA	Topography & timber cover
Fish stream habitat	1978	1:20 000	MB	Fishery habitat inventory				

* MOEP — B.C. Ministry of Environment and Parks

MB — MacMillan Bloedel Limited

CIPA — CIPA Lumber Company Ltd.

FFIP — Fish/Forestry Interaction Program

^b Townshend (1979).^c Sutherland-Brown (1968).

3.1 Aerial Photographs

The aerial photographs used for producing contour maps for timber, terrain, and soil typing must be up-to-date and of the highest possible quality.

3.2 Topographic Maps

The topographic map, at a scale of 1:20 000 or 1:5000, is the primary means of presenting all current logging plans. Maps are used for field work and for preparing alternative plans. For decades, coastal logging maps (scale 1:4800) were made in combination with timber cruising by ground surveying. Today, aerial photographs are used to prepare the contour maps that identify timber types. Good topographic maps can increase the effectiveness of plans and reduce the need for field verification.

Field layout people generally rely on field observation to compensate for any localized loss of map accuracy. If a contour map is unreliable, it becomes a hindrance. The detail on topographic maps used in the study varied greatly according to which individual or company prepared the map.

FERIC prepared detailed maps from ground surveys of the Hangover Creek and Phantom Creek study areas, at a scale of 1:2500 with 5-m contours. Figure 2 shows the detail provided by the FERIC ground-based map as compared to an industry aerial-photo map of the same area.

The advantage of ground mapping areas subject to mass wasting is that it provides a systematic examination of several aspects of the area to be logged, including:

- local benches, obstacles, and rock outcrops that could be obscured by tree cover;
- creeks and gullies;
- soils and sensitive areas.

Ground mapping, however, also has some disadvantages:

- It is expensive and time consuming. The two-man FERIC crews mapped 12 ha/day (estimated cost \$25/ha). In addition, surveyed base lines are required and the map must be prepared and inked.
- Experienced field people who can recognize relevant features are required.
- Detail varies with different field crews, and information collected along and immediately adjacent to strips was more accurate than details midway between strips.

New mapping techniques, such as automated laser contouring (Breadon and Nagy 1984), overcome the limitations of cloud, shadow, and dense timber; but current high-quality aerial photography and optical plotting, combined with skilled plotters/mappers, is still the best technique available.

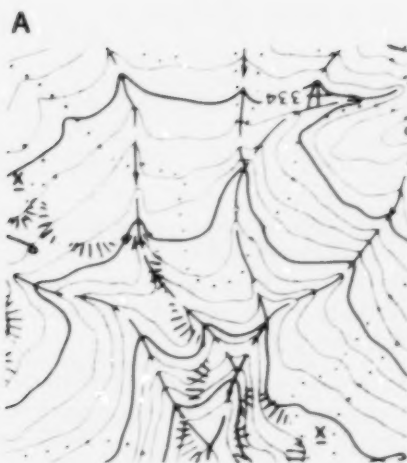
3.3 Terrain and Stability Mapping

Information about bedrock geology, surficial material, and landforms is used to produce terrain and stability maps (Figure 3). Terrain maps delineate the surficial geology and geomorphic processes, and not areas where a landslide may occur. Stability maps are interpretations of the potential for failures to occur on various terrain units, as a result of logging activities.

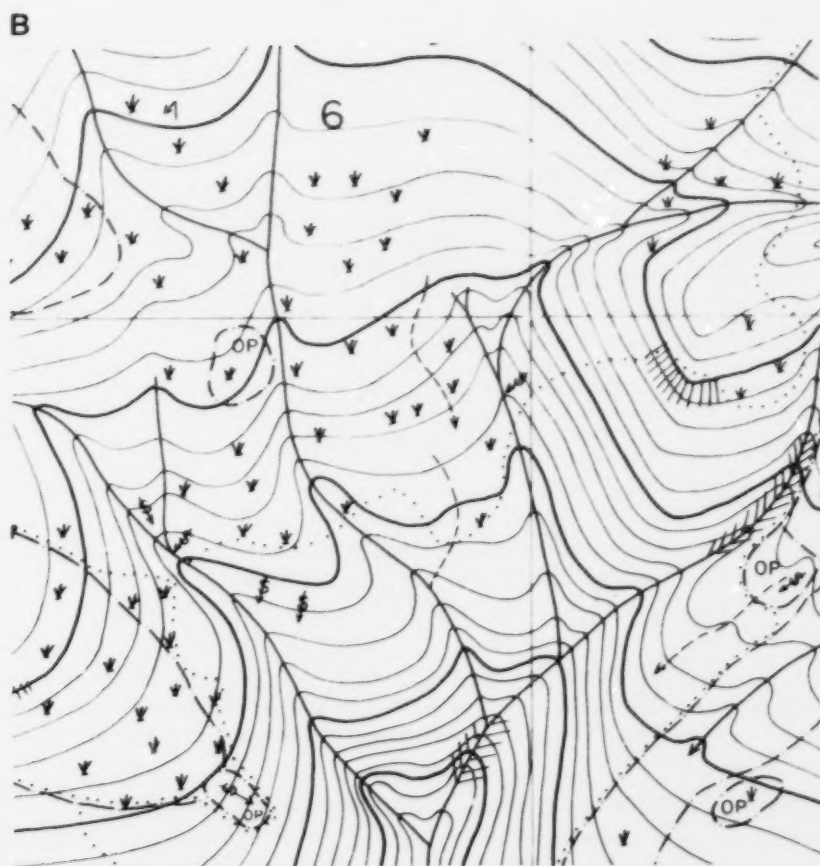
For example, the maps shown in Figure 4 are prepared by two different methods and both are accurate. The MacMillan Bloedel map was prepared from aerial photographs by one expert in 2 days, and a terrain specialist took 1 day to field-check specific areas. The FERIC map took two experts 15 days to prepare, and also required a significant amount of field-mapping time.

Soil texture, soil depth to a consolidated layer, and soil moisture are used to assess slope stability. These factors influence shear strength (Sidle, *et al.* 1985; Sauder, *et al.* 1987). Soil instability is assumed to increase as soils become finer textured, as slope increases, and as soil moisture increases. This information is incorporated with information on bedrock geology and landforms to produce terrain maps.

FERIC found that soil pits were useful for determining the variability in surficial deposits over a slope and for assessing road construction difficulty. Landslides were also examined to determine local site characteristics that may indicate the potential for slope failure.



1:5000 photogeometric
topographic map with
25-ft contour intervals.



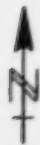
1:2500 ground
survey topo-
graphic map with
5-m contour
intervals.

FIGURE 2: Comparison of map details. (A) Map prepared from aerial photographs (MacMillan Bloedel Map Sheet 103F.039.1.3), and (B) map prepared from FERIC ground surveys.

1. No instability problems.
2. Potential for minor induced failures.
3. Potential minor instability problems.
4. Instability problems may develop.
5. Significant stability problems may develop.



MacMillan Bloedel Terrain Stability Mapping
Scale 1:20 000



FERIC Terrain Analysis
Scale 1:2500
(reduced to 1:20 000)
Class 5 areas delineated

FIGURE 4: Comparison of geotechnic maps produced at different scales and different levels of field work.

Soil moisture over relatively large areas can be identified on black and white aerial photographs with the use of indicators such as stand composition and location of the site within the landscape.

FERIC's soil-moisture classification system used plant indicators and lushness of vegetation to detect relative changes in soil moisture along the survey lines. At the time of FERIC's surveys, the local Queen Charlotte Islands vegetative indicators and their relationship to soil moisture were not extensively documented. Since that time, the Ministry of Forests has developed an ecosystem classification for the Coastal Western-Hemlock biogeoclimatic zone (Queen Charlotte subzone), and a large portion of the future operating area has been mapped.

The soil-moisture regimes identified from the survey were useful in determining potential road construction problem sites and areas where yarding disturbance may interrupt groundwater drainage. The time required to assess the soil moisture at each plot was relatively short.

Most terrain mapping and slope stability interpretation is based on 1:20 000 mapping with field checking. The smallest terrain unit mapped at this scale is about 4 ha (Ryder and Howes 1984). Terrain specialists undertake to bring terrain mapping up to a 1:5000 scale by field reviews of areas planned for development. Accurate boundaries between units and the location of small potential failure sites can only be determined by field examination. Enlarging a stability map to a 1:5000 scale without additional field work may result in misinterpretation, and give the appearance of greater detail than the original data can support.

3.3.1 Slope stability classification

On the Queen Charlotte Islands, four systems are currently being used for slope stability analysis.

Each system has its own detailed harvesting prescription for the various terrain units. The variation in systems and prescriptions shows the variability in operating areas on the Queen Charlotte Islands, and reflects the different uses industry has for the information. The number of field plots established to verify typing varies according to the mapper and the contract negotiated.

At Hangover Creek and Phantom Creek, FERIC's intensive ground surveys delineated specific rather than general areas of potentially unstable ground in a five-class system. In effect, FERIC's stability mapping refined basic mapping by undertaking the detailed field work needed to expand the scale accurately.

During FERIC's reconnaissance and map layout, extensive areas of potential instability were noted within areas previously defined as "stable" units, and areas of stable ground were found in "unstable" units. This confirmed the importance of thorough field reconnaissance and the risk of becoming complacent with layout on "stable" terrain units.

Terrain stability mapping is particularly effective when the users understand the basic system and know how the coding was derived. Currently, the operations people assist in the mapping, and as a result terrain stability has become part of the basic information used for successful planning.

The cost of terrain stability mapping depends on the access available for field verification of photograph typing, the number of field plots required, and the experience of the terrain specialist. On the Queen Charlotte Islands, terrain mapping costs have ranged between \$1.11 and 4.30/ha.

3.4 Timber Inventory and Cruises

Timber inventories are determined by the analysis of timber type maps, which are made from aerial photographs, and of data derived from sample plots of timber types and timber type maps.

FERIC undertook a detailed timber cruise of each of the study areas on a systematic plot basis to determine the requirements of timber-volume and timber quality information for layout and economic analysis.

An experienced layout engineer can usually estimate the stand characteristics. However, where specialized yarding methods are contemplated, this information may be supplemented or checked with a field cruise. Tree sizes and timber quality are especially important when the use of yarding methods is considered. A helicopter-logging system requires the timber size to be matched to the helicopter's carrying capacity.

Skyline-yarding systems that can fully suspend logs over sensitive terrain or gullies must have adequate deflection and be capable of supporting the heaviest and longest logs.

The justification for logging depends on the grade and value of the trees in relation to the extraction and transportation costs. The timber values may be difficult to estimate in mixed stands, and cruise information may be required.

3.5 Knowledge of Road and Logging Systems

During road location and logging layout, the road construction equipment and logging system must be matched to the terrain. The planner must therefore understand how the systems operate, where each works best, and which factors affect productivity and contribute to initiation of mass wasting. Conflicts and misunderstandings have occurred in the past because proposed methods would not work in the designated terrain. All individuals involved in planning and planning assessment should be encouraged to observe operations and to talk to loggers and construction workers.

3.6 Stream Classification

A system of stream classification that indicates how landslide debris may affect a stream channel allows for the assessment of potential landslide impacts. A simplified stream classification system was established by FFIP (Poulin 1981), based on three instability conditions that could exist within basins and lead to the introduction of debris and sediment into a stream channel (Figure 5). These conditions are:

1. A landslide entering the steep headwall tributaries is assumed to have a high probability of initiating a debris torrent that could affect the lower sections.
2. Landslides occurring on the slopes along the mid-portions of the stream will likely deposit debris into the channel or along the bank (Figure 6).
3. Landslides occurring along the side slope adjacent to a flood plain will probably not enter the creek.

The classification lacks specific details but provides a systematic appraisal of landslide tracks that a planner can use in conjunction with personal experience. Experience from other areas can be used to predict deposition areas and the effects of landslide travel.

3.7 Statistical Geographical Terrain Unit Mapping

MacMillan Bloedel Limited and the Ministry of Environment (Sondheim and Rollerson 1985) have initiated work on a mapping technique that incorporates data collected from landslide survey inventories and terrain mapping, and assigns a probability of failure for specific terrain units (Rollerson 1984). The system has been developed on Vancouver Island and has promise for the Queen Charlotte Islands.

3.8 Mathematical Modelling of Slope Stability

Organizations in the United States and Japan have designed several models that attempt to predict mathematically the probability of a slope movement occurring either in natural timber or in areas disturbed by logging. Generally, the models are based on methods of estimating limiting slope equilibrium and on soil deformation analysis (Morgenstern and Sangrey 1978; Wu and Sangrey 1978).

FERIC reviewed several systems and discussed them with researchers who were working with specific models. While the concept of mathematical modelling is a good one, there are a number of limitations. For the models to be useful, engineering properties of soils and rock must be obtained by detailed soil sampling and laboratory analysis. The resulting models are accurate for site-specific areas, and are costly to apply. Sirmon (1985), when summarizing "A Workshop on Slope Stability," concluded that different degrees of reliability for landslide prediction exist, depending on the failure mechanism, inventory levels, data type (rock, soil, climate), and past experience.

Mathematical models are used to sort through a large amount of complex data in an orderly manner, and to produce consistent results.



FIGURE 5: Three basic stream or reach types found in areas of intensive mass wasting on the Queen Charlotte Islands (Poulin 1981).

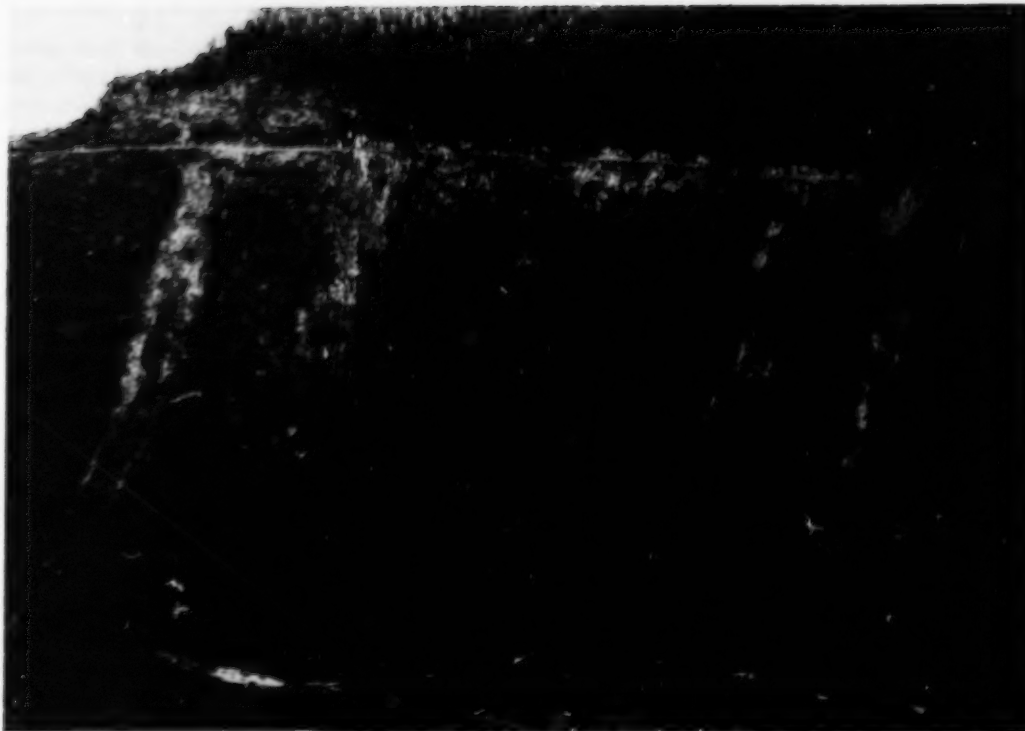


FIGURE 6: Failures from road construction along Stream Type II.

3.9 Data Collection Alternatives

If a good base map is available, a detailed systematic survey of a potential logging area is not required. However, additional detail for **small critical areas** may be added by ground mapping. Specific data can also be collected during the initial road location.

The time of year during which data are collected is also important. FERIC collected the field information for the Phantom Creek and Hangover Creek study areas during the late spring, summer, and fall. During the dry summer, data collection was easier and, therefore, probably more accurate. However, detail was lacking on surface and subsurface water flows, and indicator plants were used to note relative changes in soil moisture. During and after wet weather, small intermittent watercourses were obvious and subsurface water patterns could be identified. This information was useful in locating specific areas of potential instability, and in planning road drainage structures.

4 PREPARATION OF ALTERNATIVE LOGGING PLANS

The preparation of more than one logging plan forces the planners to critically analyze and compare alternative methods of harvesting the timber. The plan that best meets the overall objectives can then be implemented.

The preparation of a logging plan is a complex task that requires the integration of a vast amount of data. The detail proposed in the plan must be consistent with the accuracy of the data and map. Unrealistic plans based on insufficient data are misleading and may provoke unnecessary controversy between planners and agencies. A logging plan must not only resolve the physical problems of building roads and logging, but must also assess the environmental effects and evaluate economic costs and values.

A plan must provide current logging layouts, and define the road access to timber beyond the current development. It must also provide the transition between the longer-term development plan and the cutting permit. The actual plan submitted for a cutting permit is often only a portion of an overall plan. The cutting permit may appear to propose "second-best choices" when viewed alone, but these compromises may be necessary to achieve the best plan for the total area.

Three logging plans were prepared for each of the ground-mapped areas, Phantom and Hangover Creeks. In addition, the use of long-distance skylines was examined. Plans were prepared using the topographic map sheet as a base. Stability and timber volume information was sketched on the base map, and roads, landings, and setting boundaries were projected. Intensive mapping ensured that topographic detail was sufficiently accurate for detailed layouts and critical analysis.

The proposed alternative plans for logging Hangover Creek and Phantom Creek are:

1. Highlead system — The primary highlead-yarding system would be supplemented by short-yarding along the road right-of-way. This layout would use the most common logging systems available, including the mobile yarding crane.
2. Skyline system — Skyline tower yarders and mobile yarding cranes would be used to maximum advantage, and would be supplemented by the systems in the highlead layout. This layout would require equipment that was more varied. It is expected that road lengths and landings would be reduced because of the long-distance yarding capability of the yarders.
3. Helicopter system — Helicopter yarding was proposed for logging the upper and middle slopes, supplemented by a mobile yarding crane and highlead yarding on the lower slopes.

In preparing plans for the Hangover Creek and Phantom Creek study, FERIC's objectives were as follows:

- to develop as much commercially valuable timber as possible.
- to identify areas of marginally valuable timber and adjoining areas for future logging development.
- to minimize road lengths on mid-slopes.
- to take advantage of ridge-top roads.
- to minimize total logging cost.
- to minimize disturbance to Stability Classes III and IV terrain units.
- to avoid, as much as possible, road disturbance on Stability Classes IV and V, and yarding disturbance on Class V areas.

4.1 Description of the Planning Areas

Both the Phantom Creek and Hangover Creek areas would be difficult to log because they are characterized by steep slopes, unstable sites, and areas of sub-merchantable timber. Table 4 shows the merchantable volume of timber and species distribution. Phantom Creek contains only 373 m³/ha and Hangover Creek only 399 m³/ha, because areas of scattered low-volume trees and scrub are included. This is typical of the Queen Charlotte Islands forests, where roads are built through non-merchantable timber stands.

Table 5 shows the slope class by area. The slope classes were selected to conform with the digital terrain model output and to take into account that slopes between 38° and 42° are generally at the soil's natural angle of repose. In both locations, approximately 60% of the area consists of gentle slopes of less than 45%.

TABLE 4. Timber volume: Phantom Creek and Hangover Creek

Species	Timber volume ^a (close utilization — m ³)			
	Phantom — 146 ha		Hangover — 429 ha	
	m ³	% of total	m ³	% of total
Cedar	431	1	17 265	10
Hemlock	27 519	50	76 637	45
Spruce	14 648	27	54 210	32
Yellow-cedar	11 823	22	20 088	12
Mountain hemlock	79	0		
Lodgepole pine	—	—	437	0
Total conifer	54 501	100	168 636	99
Alder	—	—	2 483	1
Total	54 501	100	171 119	100
Average volume/ha	373		399	

^a Gross volume less decay, waste, and breakage.
 Min. DBH — 17.5 cm
 Stump height — 30.0 cm
 Top diameter — 15.0 cm

TABLE 5. Slope-class distribution by area: Phantom Creek and Hangover Creek

Slope range (%)	Approx. range (deg)	Phantom Creek		Hangover Creek	
		Area (ha)	% of total	Area (ha)	% of total
0-25	0-14	32	22	150	35
26-45	15-24	59	40	111	26
46-55	25-29	19	13	44	10
56-65	30-33	15	10	41	10
66-75	34-37	10	7	34	8
76-90	38-42	8	6	32	8
91-105	43-46	2	1	9	2
106-130	47-52	1	1	6	1
131-155	53-57			1	<1
156-175	58-60			1	<1
Total		146	100	429	100

TABLE 6. Slope stability classification^a by area: Phantom Creek and Hangover Creek

Slope stability class	Phantom		Hangover	
	Area (ha)	% of total	Area (ha)	% of total
I ^b	5.2	4	64.3	15
II	33.9	25	60.1	14
III	47.4	34	106.1	26
IV	29.7	21	44.5	11
V	22.0	16	143.7	34
Total	138.2	100	418.7	100

^a FERIC system based on intensive ground mapping.
^b Most stable slope.

and 10% consists of extremely steep slopes over 75%. Table 6 shows the slope stability classification by unit area. Phantom Creek has stable slopes on 29% of its area (Classes I and II) and unstable slopes on 37% (Classes IV and V). Hangover Creek also has stable slopes, on 29% of its area, but 45% of the slopes are unstable.

Plans were made with the assumptions that road construction and yarding practices would be those in current use (Tables 7 and 8); that backspars would be used where necessary to provide increased lift; and that tailholds would be located to maximize deflection. It was also assumed that up- and down-slope yarding would be maximized and cross-slope yarding would be minimized.

TABLE 7. Branch- and spur-road specifications applied to layout

Speed	40–60 km/hr
Gradient	Favourable: 20% maximum (for short lengths) Adverse: 8% maximum
Surface width	4.9 m
Subgrade width	6.0 m (5.2 m minimum) and ditch
Ditch	0.6 m × 0.3 m minimum
Culvert size	Wood material only: 1.8 m × 0.6 m minimum opening
Cut slope	Up to 100%, depending on material type or vertical in rock
Fill slope	Up to 100%, depending on material

TABLE 8. General specifications for yarding equipment applied to layout

Yarder	Tower/gantry height (m)	Optimum external yarding distance (m)	Comments
Highlead tower	27.5	210 convex slope 180 straight slope 270 long corner	2-drum yarder with tower.
Grapple yarder	15.0	120 180 maximum	3-drum converted cable log loader on a mobile carrier used only for grapple logging (non-interlocked).
Yarding crane	18.5	180 360 maximum	3-drum interlock yarder on a mobile carrier with swing capability. Operates in the running skyline mode. Grapple or dropline carriage capability.
Slackline tower	33.5	360 420 maximum	3- or 4-drum yarder capable of operating in live skyline, slackline, or North Bend mode.
Helicopter		1600	3600 kg+ lift capacity helicopter converted for logging. Assumes the presence of a small support helicopter to transport crew and ferry chokers to the log pick-up zone.

4.2 Highlead-Yarding Plans

The plan for the Phantom Creek area, which includes the use of highlead yarders as the primary system and short-reach grapple yarding as a secondary system, is representative of techniques used in the early 1970's. For Hangover Creek, the highlead plan makes more use of yarding cranes, so the plan is more typical of current methods. Figure 7 is the checklist used to develop the highlead plan.

Planning began with the noting of key control points that could limit road location, setting layout, or access to adjacent timber. Potential areas of slope instability, determined by surficial mapping, were located on the topographic maps. Notes were made of potential landing sites that would provide access to the majority of the timber. Road locations that would take advantage of natural ground breaks, minimize rock cuts on steep side slopes, and minimize deep gully crossings were proposed. Landings and road locations were then adjusted so that timber between the natural landings could be developed.

The road network was superimposed on the map, with more alternative road locations being available on lower, gentler slopes. Areas with potential instability were avoided where possible, and reasonable road gradients were maintained (Figures 8 and 9). When ideal landing locations could not be accessed by a road, alternative landings were chosen. During the planning process, the planning objectives were continually reviewed.

As the plans were being prepared, trade-offs were made between landing location and the potential for good yarding. The yarding quality was assessed according to slope profiles and deflection lines along proposed cable pathways (Figure 10). A target deflection of 8% was chosen for all systems. Deflection was reduced to 5% and backspars (optimum height 3–5 m, maximum height 10 m) were proposed when ground lead was encountered at less than optimum or maximum yarding distance.

Once the original plan was completed, areas of difficult logging and areas of logging on environmentally sensitive terrain were noted ("flagged") for field examination.

Highlead landings or roads that would develop only small volumes of low-value timber were re-examined to determine whether or not alternative landings could develop the timber from the established road network.

After a workable plan was developed, the environmental criteria were examined in detail and the plan was modified. Timber boundaries were assessed for wind firmness according to soil texture, soil moisture, prevailing winds, soil depth, and tree height. The geotechnical and slope stability data were re-examined. Road location alternatives were studied where the roads would intersect unstable areas. When the road location could not be moved to avoid unstable areas and where the construction costs to maintain stability were estimated to be high, the timber values accessed by current and future roads were re-examined to determine whether or not the logging plan would be economical. Yarding-road profiles that indicated a high potential for ground disturbance on unstable areas were also re-examined. The complete setting was finally assessed to determine whether changes in the yarding boundaries, landing, or yarding system would reduce disturbance.

Although topography limited alternatives for the Phantom Creek highlead access road, the plan developed some good highlead settings. Highlead layout of Hangover Creek was difficult because the undulating terrain on the lower slopes and the steep, rocky, and gullied terrain on the midslope reduced deflection. The proposed road across the middle portion of the east side and over the major gully would be difficult and expensive to construct. If construction of this portion were not possible, then approximately 50 ha of timber would be isolated and subject to blowdown if settings above and below are logged. In both areas, the highlead settings on the steep upper slopes should be relatively narrow to avoid cross-slope yarding. This would result in greater than normal landing changes.

4.3 Skyline-Yarding Plans

The same process used to develop the highlead plan was used to prepare an alternative plan for skyline yarding. The skyline system uses a cable stretched between the spar and tailhold to support a carriage. This system provides lift directly over the logs, which become fully or partially suspended. In addition, skyline yarders have greater cable capacities than conventional yarders, so yarding distances can be extended.

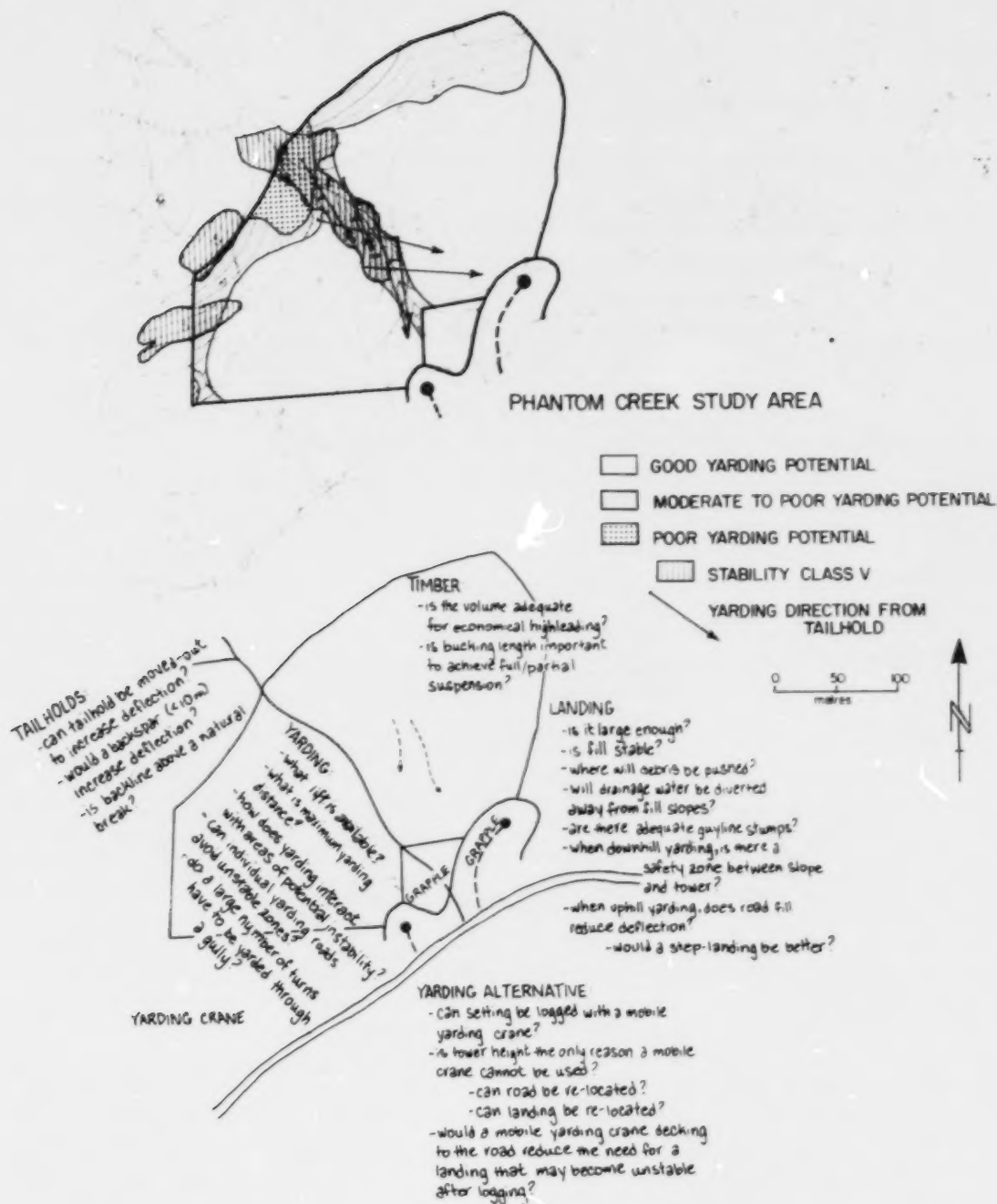


FIGURE 7: Checklist for highlead-yarding planning, Phantom Creek.

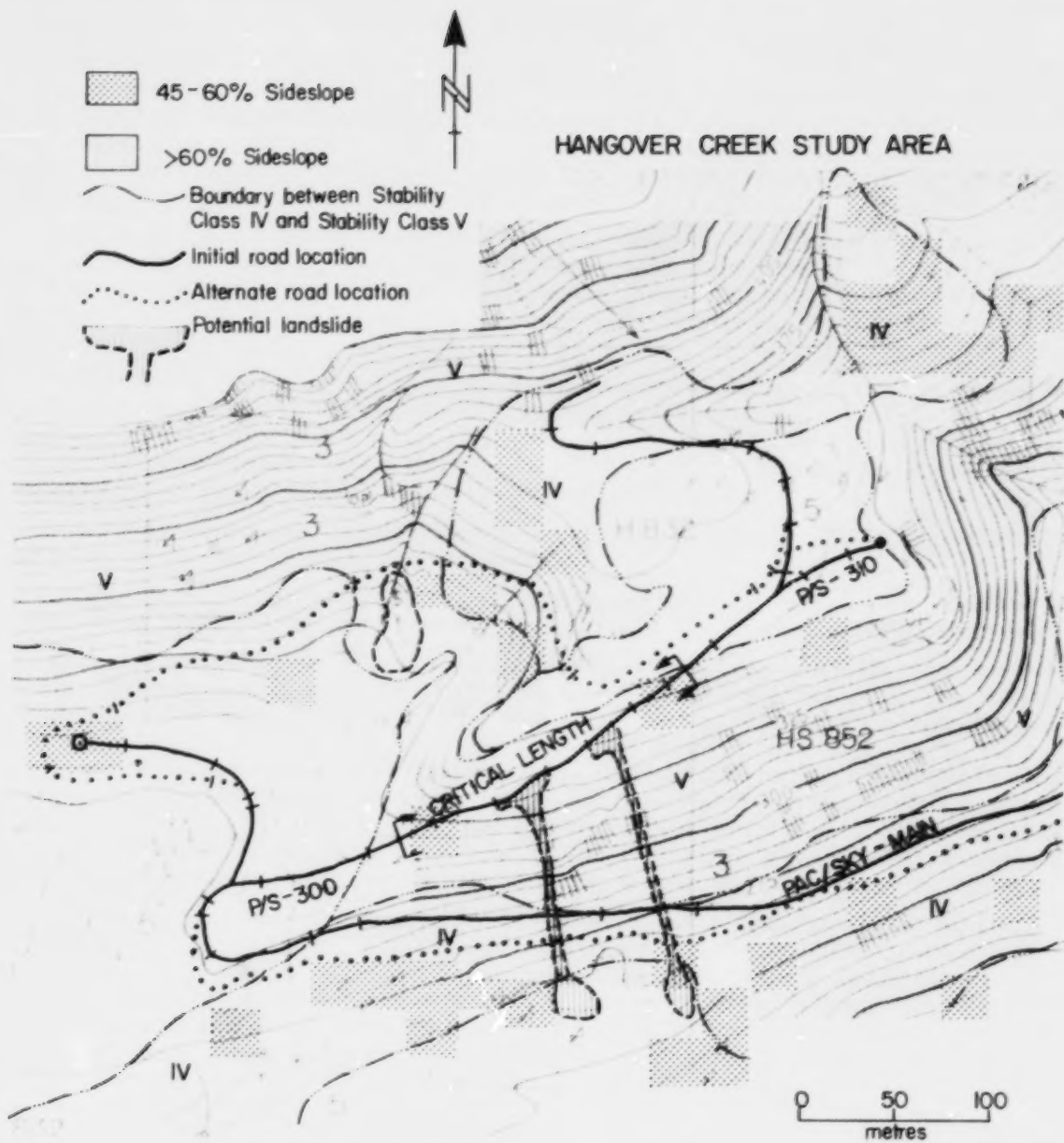


FIGURE 8: Road location alternatives for critical length along P/S-300.

Original location:

- climbing road at 15-18% -- cannot get onto stable ridge location
- if a slide should occur, there is a good chance it would travel to/past the main road below
- reducing grade on road would not help

Alternate location:

- portion of road through class IV - requires careful construction - less class V than original
- potential for a slide at a previous slide, however debris would not travel very far (flat terrain 25m below)
- also potential for a short debris torrent if culvert or fill material improperly placed as road crosses intermittent creeks - requires careful placement of fill (class IV terrain)
- longer route location - could be more expensive to construct, though easier
- care required around the top of the headwall area of low gradient streams

FIGURE 9: Notes from assessment of alternative road locations.

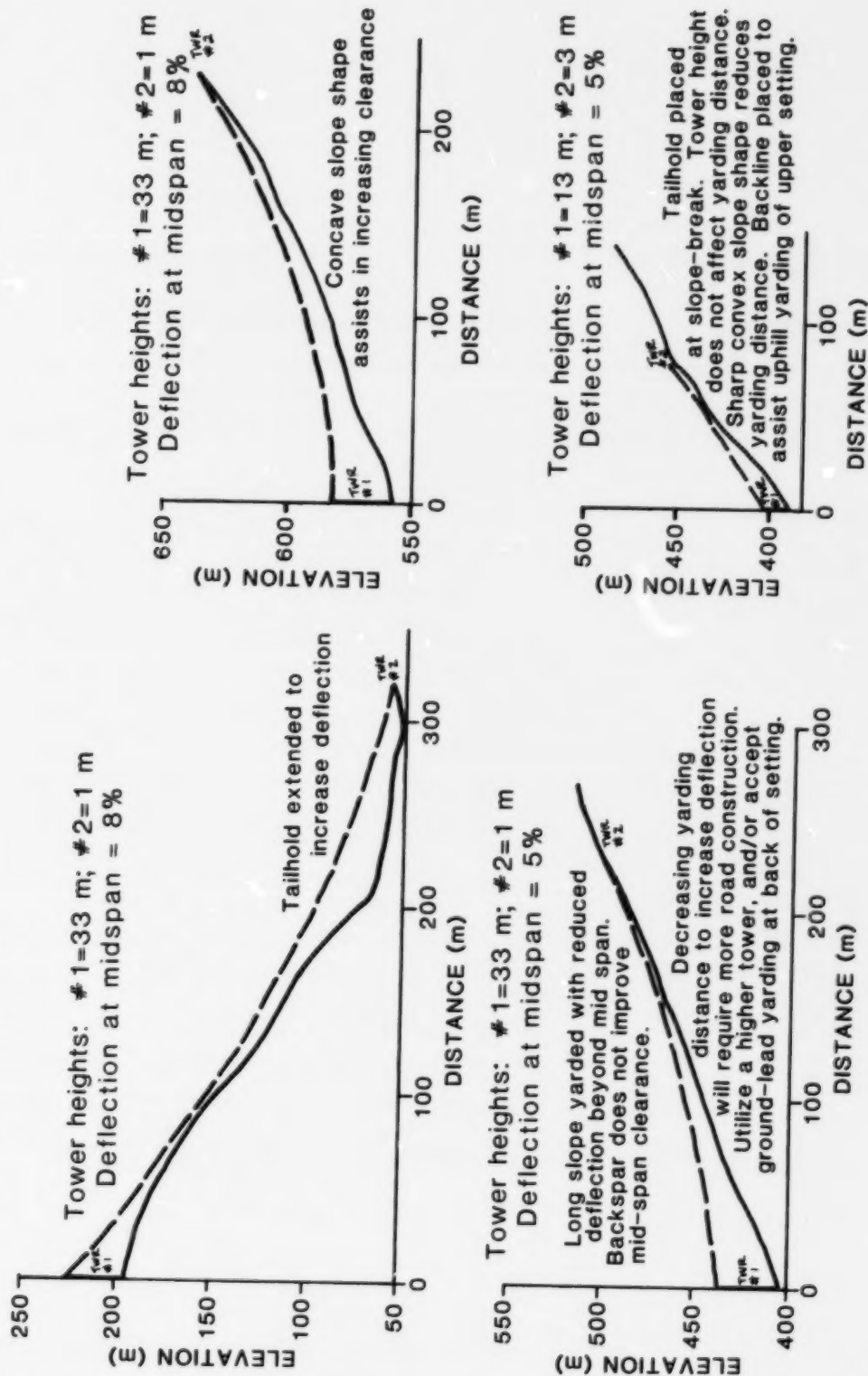


FIGURE 10: Yarding profiles derived from study areas.

Skyline logging could be used at yarding distances of 330–600 m. It offers full-suspension capability over gullies or potentially sensitive terrain where there is sufficient ground clearance. The particular skyline system chosen would be left to the yarding crew. A live skyline (gravity) would work for some of the uphill yarding areas, and slackline or North Bend would work for all the remaining areas. Yarding cranes with interlocked winches and a dropline carriage could also be used as a skyline system.

As with the highlead plans, the final skyline plan is a compromise among economic, operational, and environmental requirements. Where they would produce better results, highlead and grapple yarders would be used to supplement the skyline yarders. Figures 11, 12, and 13 are checklists that were prepared for assessing the potential for various skyline systems.

The road layout plans for the Phantom Creek skyline layout resulted in the re-routing and shortening of the main road, and the elimination of a spur road. The cutting boundary up to the ridge would extend slightly towards the northeast corner. Road location would be similar to that for the highlead because of the restricted access up the slope.

The Phantom skyline layout would produce more timber than the highlead layout because it would access the northeast quarter. The cutting boundary would be adjusted during field location so that yarding disturbance of sensitive terrain and exposure to prevailing storm winds are minimized. This layout isolates 5 ha of timber in the lower north-west corner. The terrain is too rugged for road access and deflection is not available for cable yarding.

The skyline layouts of the Hangover Creek plan show only a few good skyline landings. A marginal deflection of 5% is available over most of the skyline settings. It is assumed good tailholds would be available; they would need to be verified before actual logging would start. The greatest benefit of the skyline layout is its potential to improve lift by extending the skyline to a tailhold that takes advantage of natural ridges or breaks. In addition, the road network that would access the upper slopes would develop a large number of good highlead and mobile yarding-crane settings on the lower and mid slopes.

Road access to the Hangover upper slope is restricted because of the deep gullies, rock outcrops, steep side slopes, and sensitive terrain. Any road development to upper slopes would require some construction across steep Class V sites. Also, yarding disturbance to sensitive sites could not be avoided by using full suspension, because the necessary deflection is often not available.

The outside boundary of the Hangover skyline layout is extremely irregular and would require field checking to minimize windfall.

4.4 Helicopter-Yarding Plans

Helicopter logging plans indicated that road lengths and potential yarding disturbance over sensitive terrain would be kept to a minimum. While helicopter logging has been undertaken on slopes on the British Columbia coast and in the U.S. Pacific Northwest, none had been undertaken on the Queen Charlotte Islands during the course of the study. The detailed helicopter layout demonstrated the problem of balancing helicopter logging with conventional cable systems.

Helicopter settings were proposed to log timber that would normally be accessed by a road built through unstable terrain (primarily on the mid-slopes), or to remove timber that would be too difficult to yard by conventional means. Figure 14 provides the checklist of points used to consider the proposed helicopter logging plan, and to evaluate adjacent conventional logging settings.

Yarding small, isolated timber patches by helicopter would be economical only if a sufficient volume of wood were available to offset set-up costs. Once the economic viability is assured, smaller areas can be re-examined to see if conventional yarding could be replaced.

It was proposed that the helicopter be used to yard logs out of the gullies where the conventional cable systems could not easily reach, and in areas of difficult yarding on unstable slopes (Figure 15). This localized use of the helicopter to yard out the "difficult" portions of conventional settings is an important advantage of helicopter logging.

For a large portion of the Phantom Creek plan, it was proposed that the few high-value trees be selectively logged by helicopter while the majority of the trees, which are of low value, be left standing. It was assumed that this would help maintain a stable slope by ensuring a living root network.



FIGURE 11: Checklist for mobile yarding-crane planning, Hangover Creek.

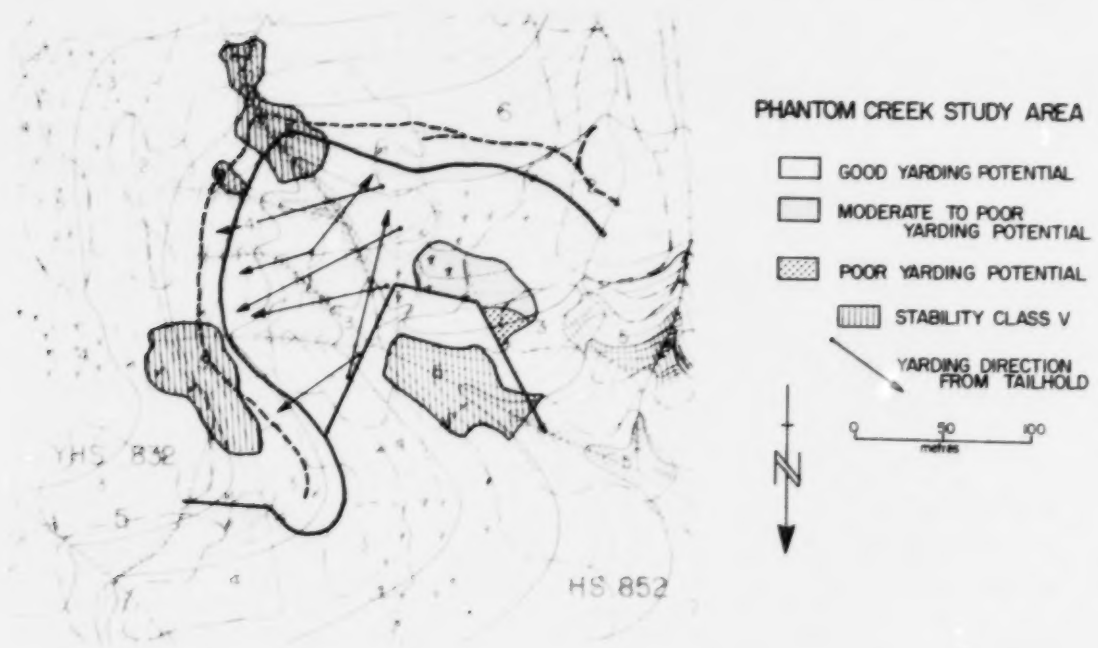


FIGURE 13: Checklist for mobile yarding-crane planning, Phantom Creek.

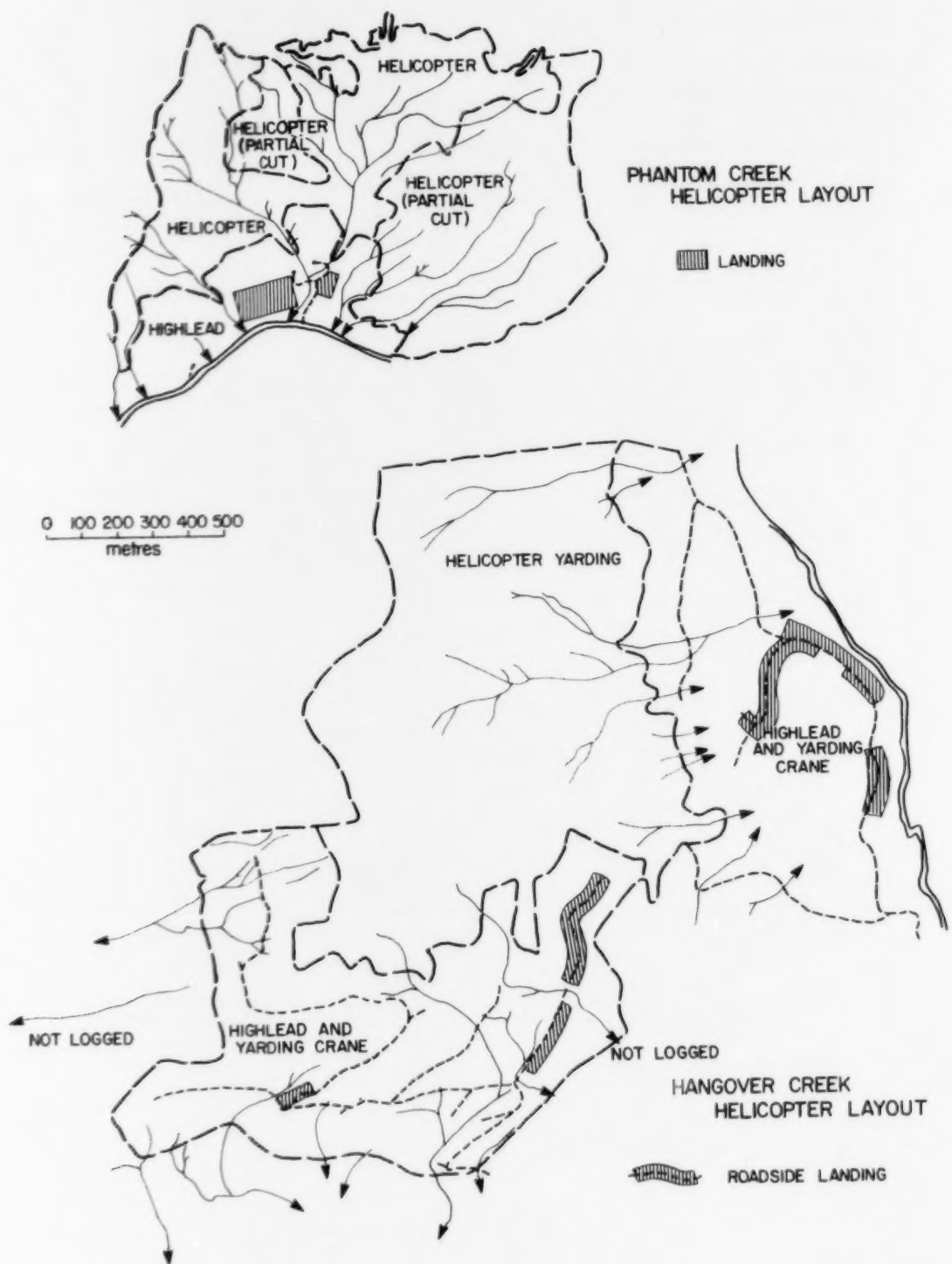


FIGURE 14: Checklist for helicopter-logging planning, Phantom Creek and Hangover Creek.

LANDING ALTERNATIVES:

- water drop
 - allows for storage of large quantities of logs before processing
 - boats must be used to collect chokers
 - calm, protected area required
 - disposal of debris and slash may be difficult
 - floating processing barge or float probably required
 - no problems with dust
- central drop
 - logs manufactured/processed immediately after arrival at landing
 - equipment required and operation is similar to any dry-land sort (i.e. front-end loaders)
 - chokers recovered at the drop zone
 - dust may be a problem during dry weather
 - storage of processed logs may be limited
 - relatively little area to store unprocessed logs
 - landing may quickly back-up if loader breaks down
 - loading and processing crew must work when yarding
- roadside drop
 - processing of logs and loading is completely separated from yarding
 - requires several alternative drops to avoid helicopter overflying loading crews
 - requires a skidder to pull out chokers (many may not be retrieved until loading), and a cable-type loader
 - slope beside road should not exceed 5-10% and there should be good approaches
 - landing/processing crews can work independently of yarding crews

YARDING:

- what size of helicopter will be used?
- are log size, weight and log density compatible with helicopter payload?
- are special bucking procedures required?
- what access is required for fallers, or silvicultural crews after yarding?
 - would roads reduce later management costs?
 - if so, can they be utilized for logging?
- will logs below economic yarding size contribute to accumulations of debris in gullies?
- can gullies be directionally felled so that debris accumulations are minimized?
- is opportunity taken to remove high-value trees around the cutting boundary that may be susceptible to windfall?
- are there alternative areas for yarding if weather conditions prevent logging in this area?
 - can crew and landing equipment be readily mobilized?
- is camp located nearby so advantage can be taken of short periods of good weather?
- is yarding distance within feasible economic range (i.e. between 400 and 3000 m)?

LANDING: (for decking logs)

- are there alternative areas for log storage if landing equipment breaks down?
- can helicopter descend to landing at an acceptable rate, and are approaches clear of tall trees, hills or snags?
- what are the prevailing winds? -are wind gusts likely, and from what direction?
- where will slash and debris be accumulated and how will it be disposed of?
- is there a water supply nearby for wetting landing during dry weather?

SUPPORT LANDING:

- is the storage of fuel isolated from any water courses?
- is landing protected from storms?
- can landing be surfaced with rock ballast or gravel?
- can landing be reached quickly from yarding area?

FIGURE 14: Continued.

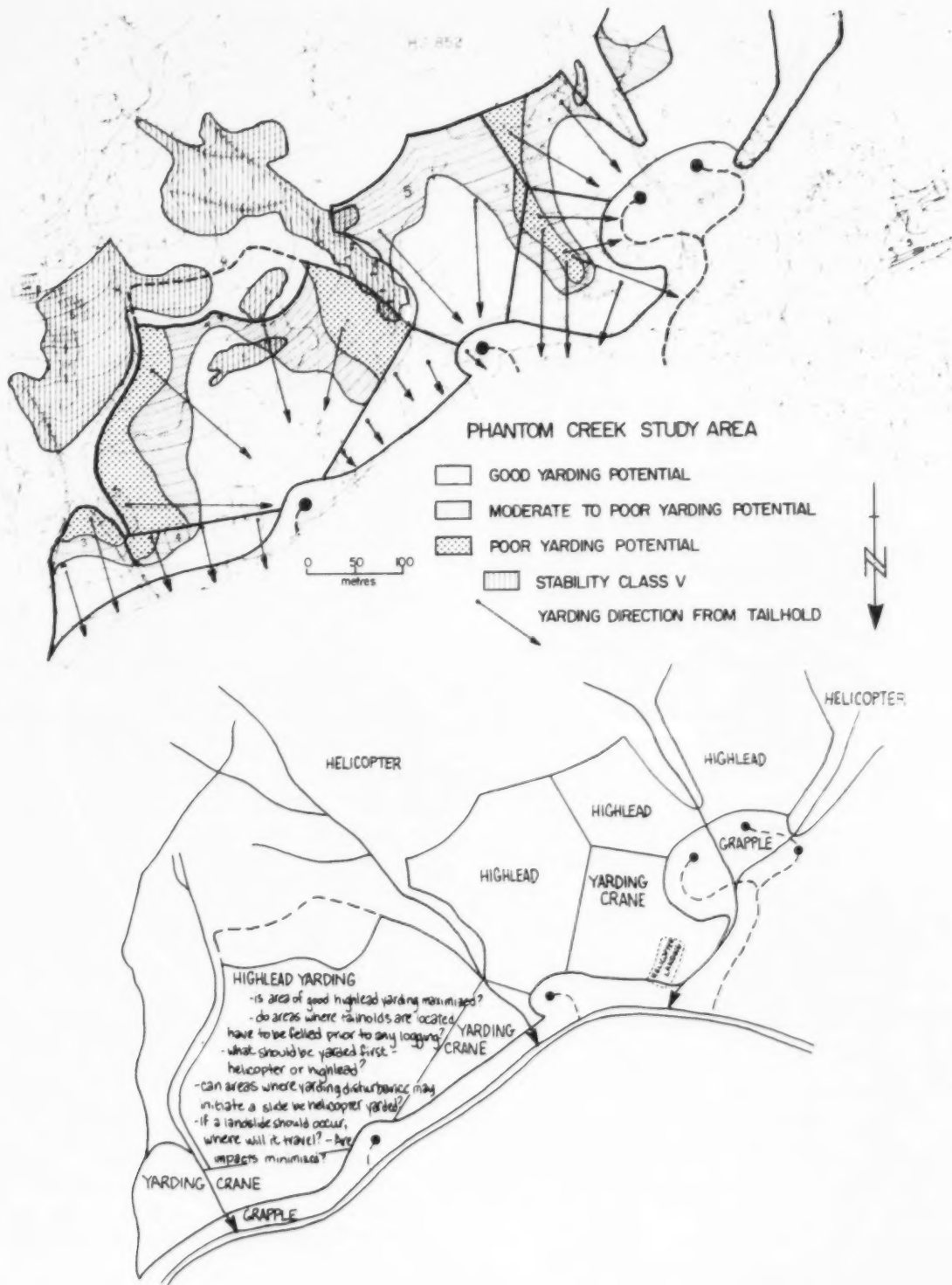


FIGURE 15: Helicopter logging would be used to reduce cable-yarding disturbance on sensitive terrain.

At Hangover Creek, the distance to a suitable, sheltered, water-drop zone would be beyond the 1.5- to 2.0-km optimum flying distance; therefore, land-based drops were planned. Areas suitable for large central landings are available or the logs could be unhooked in windrows beside a road.

The plan for helicopter logging the Hangover area demonstrates the interaction between road development, conventional yarding, and helicopter yarding. Helicopter logging was proposed for the high-value timber on the steep mid- to upper slopes where road and yarding disturbance could initiate failures directly into gullies, and where tower-skyline yarding would be difficult.

The area suitable for helicopter logging in the Hangover study site would require a considerable amount of road to develop the low-value timber on the lower slopes. It is difficult to determine where cable yarding should cease and helicopter logging should begin. The average cost of cable logging is less than that of the helicopter, but after the helicopter has moved to a site and the landings are prepared, the marginal cost of logging additional volume may be less than extending the roads for more cable logging.

4.5 Long Multispan Skylines

The feasibility of using long European-type skylines, such as the Wyssen, to yard distances to 1500 m was assessed by the plotting of sample deflection lines. These systems were found to be impractical for either the Phantom Creek or Hangover Creek areas. Because of the shape of the terrain, large areas of timber would be inaccessible to the skylines unless more truck roads were built. These roads would be located along the corridors identified in the highlead or skyline plans and would reduce the need for longline yarding.

4.6 Analysis of the Alternative Plans: Results

4.6.1 Timber harvested

Tables 9 and 10 show the timber that would be harvested by each system and each machine type in the two study areas. The total volume of wood harvested by a combination of skyline, yarding-crane, and highlead methods compared to yarding-crane and highlead alone (conventional system), would be 24% more for Phantom Creek and 2% less for Hangover Creek. The reduction in volume for Hangover Creek would occur as a result of terrain features that would restrict road access to a portion of the area, and thus preclude the possibility of using the extra yarding-distance capability of the skyline yarder. Helicopter yarding combined with the grapple and yarding-crane would recover 55% more timber at Phantom Creek than conventional yarding would, and 13% more timber at Hangover Creek.

4.6.2 Road construction

Figures 16 and 17 show the road lengths to be constructed through the stability classes for each system. In Phantom Creek, the use of the helicopter would almost eliminate the need to build roads on unstable terrain, and the skyline would require less road length than the highlead would. In the Hangover plan, the differences would follow the same pattern but would not be so pronounced. Naturally, it would be possible to eliminate all roads in both areas by using the helicopter exclusively, but this would be at greatly increased costs. It is not possible to eliminate all the roads in unstable terrain when highlead or skylines are used because it is necessary to cross unstable terrain to access adjacent timber.

Figures 18 and 19 indicate the construction difficulty. Once again, the helicopter at Phantom Creek eliminates all the difficult road building.

Table 11 shows a summary of the road construction costs derived from the 1986 Ministry of Forests Coast Stumpage Appraisal Manual. These costs are provided for comparison and do not represent the actual costs incurred by any of the cooperating companies. The details of the cost calculations are available from FERIC on request.

Table 11 also shows how the road lengths and total costs of roads vary with each system. On the Phantom Creek plan, the unit cost of the roads required for the skyline would be slightly higher than that of the highlead because it would be necessary to build difficult roads to access suitable landings. Most of the roads in the helicopter system would be required to access a landing away from the public road.

TABLE 9. Timber harvested by each system: Phantom Creek

	Highlead plan			Skyline plan			Helicopter plan		
	Area (ha)	Volume (m ³)	% ^a	Area (ha)	Volume (m ³)	% ^a	Area (ha)	Volume (m ³)	% ^a
Grapple	15.7	6 484	17	20.6	8 508	18	3.4	4 097	7
Highlead	49.0	23 372	60	15.7	7 025	15	14.4	8 292	14
Yarding-crane ..	21.1	8 140	23	27.8	11 673	25	0.0	0	0
Skyline	0.0	0	0	41.9	20 079	42	0.0	0	0
Helicopter	0.0	0	0	0.0	0	0	114.9	45 486	79
Total	85.8^b	38 996	100	106.0	47 285	100	132.7	47 875	100

^a Percentage of total volume logged by individual systems.

^b The total areas vary because the individual systems access different stands and different terrain.

TABLE 10. Timber harvested by each system: Hangover Creek

	Highlead plan			Skyline plan			Helicopter plan		
	Area (ha)	Volume (m ³)	% ^a	Area (ha)	Volume (m ³)	% ^a	Area (ha)	Volume (m ³)	% ^a
Grapple	42.4	23 461	17	37.7	19 945	14	23.2	12 853	7
Highlead	146.0	85 624	62	45.9	27 076	19	11.5	6 878	4
Yarding-crane ..	49.8	28 484	21	60.2	32 078	23	97.7	65 003	37
Skyline	0.0	0	0	09.8	61 874	44	0.0	0	0
Helicopter	0.0	0	0	0.0	0	0	138.2	92 579	52
Total	238.2^b	137 569	100	234.6	140 973	100	270.6	177 313	100

^a Percentage of total volume logged by individual systems.

^b The total areas vary because the individual systems access different stands and different terrain.

TABLE 11. Road construction costs

Major system	Phantom Creek			Hangover Creek		
	Road length (m)	Total cost (\$)	Unit cost (\$/m)	Road length (m)	Total cost (\$)	Unit cost (\$/m)
Highlead	4 100	273 000	66.79	13 860	962 000	69.43
Skyline	3 690	249 000	67.60	9 670	631 000	65.24
Helicopter	520	29 000	56.15	7 010	441 000	62.93

In the Hangover plan, the use of a skyline yarder would eliminate the high costs involved in crossing major gullies in the highlead plan. This would substantially reduce both the total cost and the unit cost of the road. The road length and cost may seem excessive in the helicopter plan, but it would be necessary to access timber on easy terrain suitable for less expensive systems of logging.

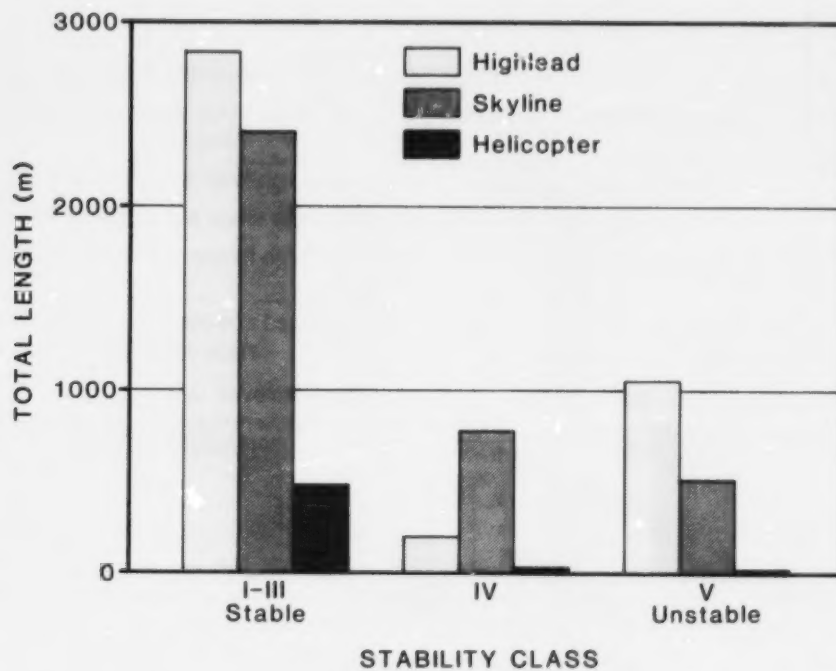


FIGURE 16: Road lengths by stability classes intersected, Phantom Creek.

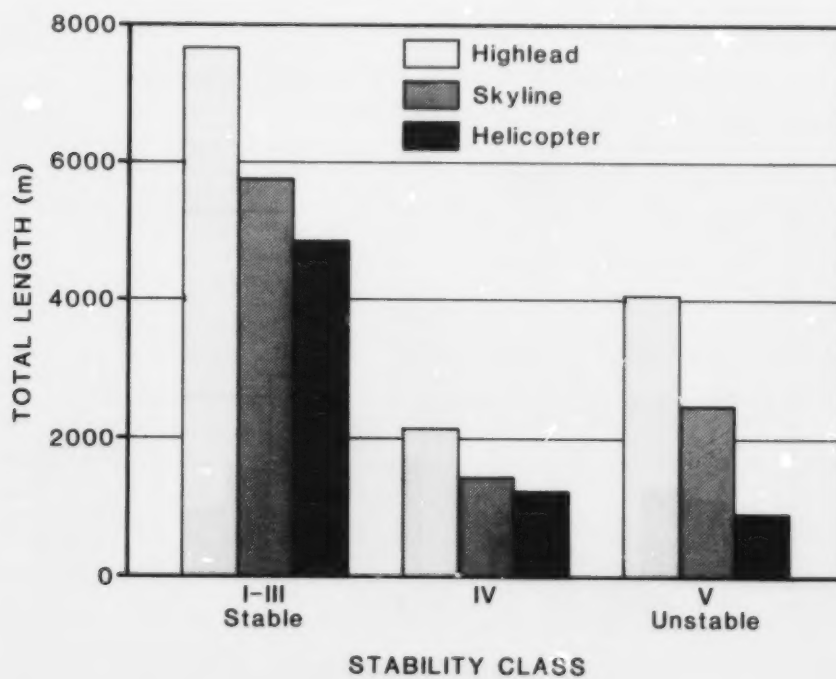


FIGURE 17: Road lengths by stability classes intersected, Hangover Creek.

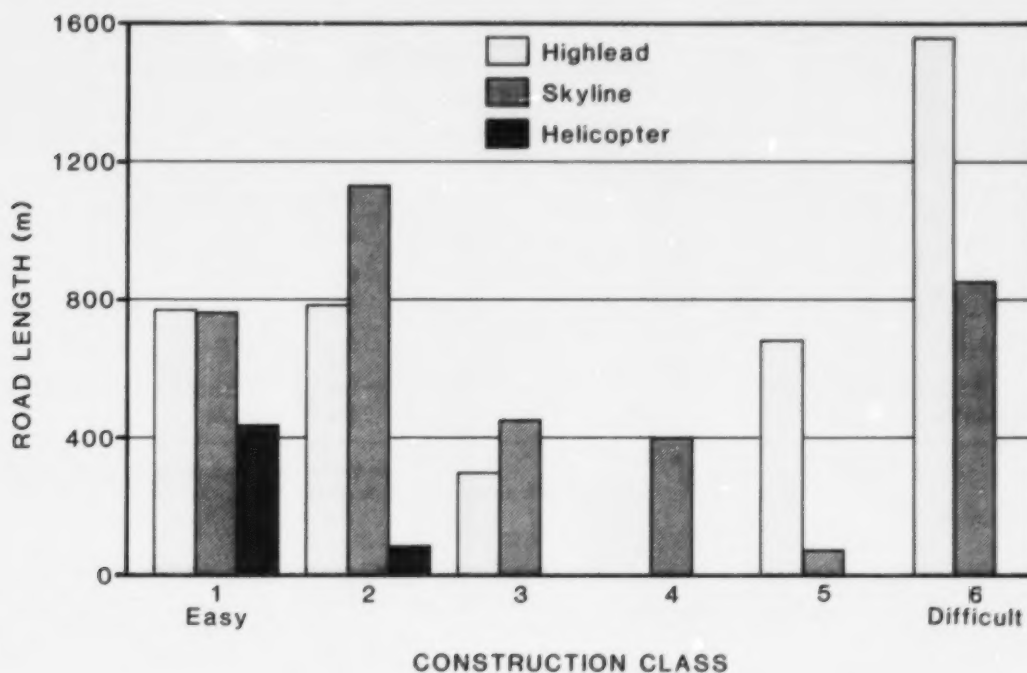


FIGURE 18: Road lengths by Ministry of Forests construction category, Phantom Creek (B.C. Ministry of Forests 1986).

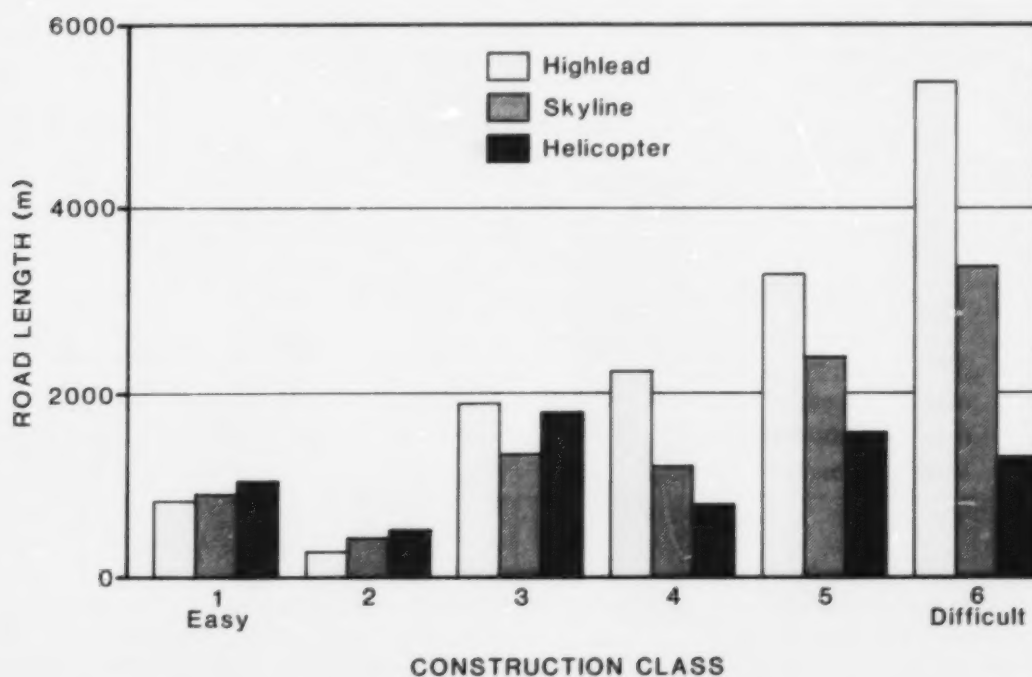


FIGURE 19: Road lengths by Ministry of Forests construction category, Hangover Creek (B.C. Ministry of Forests 1986).

Developing the alternative plans raised the following points:

1. The natural road corridors would be limited on the upper and mid-slopes, thereby reducing flexibility in making road location changes.
2. Relatively few good natural landings occur along the mid- and upper slopes.
3. The fewer the landings, the fewer alternatives available in road location.
4. The natural road corridors would develop a significant volume of timber suited to conventional yarding systems.
5. Proposed locations are trade-offs between natural slope breaks (benches and landings), environmental concerns, and construction costs.
6. The road system required to develop landings for tower skylines would not be easy to locate. Also, the cost per kilometre of construction would be relatively high because natural slope breaks are not available and gullies would have to be crossed. However, total costs could be reduced because less road would be required.

4.6.3 Yarding

Table 12 summarizes the yarding difficulty over stable and unstable ground for the proposed plans. The Hangover and Phantom sites have similar proportions of their areas in difficult and moderate yarding categories. However, significantly more of the higher instability classes are estimated to be disturbed on the Hangover area than on the Phantom area. The reason is that Hangover Creek has twice the area of higher instability than Phantom Creek. The helicopter plans have a higher proportion of areas with a good yarding chance than do the highlead and skyline plans. However, if **only** conventional equipment is used, the highlead plans would have a higher proportion of their area having a good yarding chance, compared to the skyline plan. In addition, the proportion of disturbed area having potential for slope failure would be negligible for the helicopter plan at Hangover and Phantom, and for the highlead and skyline plans at Phantom. It would be greatest for the Hangover skyline plan.

TABLE 12. Summary of yarding difficulty

Yarding difficulty	Good ^a	Moderate ^b	Moderate	Difficult ^c	Difficult	Total area
Potential for slope failure	None	Some ^d	High ^e	Some	High	
Phantom Creek						
Highlead (ha)	62	15	3	5	1	86
(%)	72	17	3	6	1	99
Skyline (ha)	71	16	3	12	1	103
(%)	69	16	3	12	1	101
Helicopter (ha)	125	6	<1	4	<1	135
(%)	93	4	0	3	0	100
Hangover Creek						
Highlead (ha)	187	20	24	3	5	239
(%)	78	8	10	1	2	99
Skyline (ha)	157	23	24	14	17	235
(%)	67	10	10	6	7	100
Helicopter (ha)	248	16	4	3	<1	271
(%)	92	6	1	1	0	100

^a Generally concave slope; good deflection or lift.

^b Straight slope; may require 2- to 5-m backspare to provide clearance for rigging.

^c Ground level and possible convex slope; requires 5- to 10-m backspare to provide deflection.

^d No significant stability problems exist.

^e Significant stability problems exist.

The potential for unfavourable yarding in the Hangover skyline plan is caused by the broken terrain. Skyline corridors with favourable deflection are limited but it is possible to build an intensive road network. The roads reduce the need for the skyline system and ensure that highlead logging operates within its limits and cross-slope yarding is minimized.

The following observations were made during the development and analysis of the alternative logging plans:

1. Trade-offs were continually required among good landing locations, good yarding, and truck road locations.
2. Ground clearance may be insufficient to suspend logs fully over the majority of sensitive sites, even with the use of backspars. Backspars could improve clearance at the back of settings, but not at the midpoints of long yarding roads.
3. Tower-skyline yarders with long-distance yarding capabilities have a greater potential than do highlead yarders for reducing truck road lengths. They do not necessarily improve yarding chance or reduce yarding disturbance, largely because of the need for good deflection. Also, longer yarding roads necessitate hauling more logs over the same ground; this would increase areas of disturbance around the landing. Skyline towers cannot be readily moved to improve yarding deflection.
4. To increase deflection, tailholds are often required to be well outside the actual setting boundaries. This would result in some actual yarding distances being two-thirds of the total line length. A benefit of the skyline yarder is that it would have the cable capacity to reach these tailholds. Tailholds would have to be prelocated. Stumps in previously logged settings may have rotted and have insufficient holding strength. The selection of some ridges and swamp areas as boundaries would have to be carefully examined in the field to determine if the stumps would be sufficient for anchors or if there would be suitable rock exposed for rock anchors.
5. No one yarding system is satisfactory for logging all the timber. For example, relatively extensive road development would be required to access the settings for skyline logging. A significant portion of the area would then have road spacing more suited for highlead or yarding-crane operations, rather than for longer-reach skylines.
6. Every setting will have some difficult yarding. Leaving isolated blocks of timber, which are then exposed to blowdown, is one option. Or, yarding could be extended, with the risk of decreasing the productivity and increasing the potential for yarding-induced slope movements. In reducing possible yarding disturbance to sensitive terrain, the theoretical optimum yarding distances were seldom realized in any of the plans.

4.7 Logging Costs and Log Values

4.7.1 Yarding and loading costs

Tables 13 and 14 show the ranges of yarding and loading costs for each machine and system for the two study areas. The road costs from the previous section are added to show the combined cost and amount of money involved. Note that felling and bucking costs are not included. These costs were compiled by FERIC and do not represent the actual costs incurred by any of the cooperating companies. These costs include allowances for the ownership and operation of machines, but do not include interest on investment, supervision, or administration. Details are available from FERIC.

The ranges in yarding and loading costs are not related to major delays or shutdowns; rather, they result from variations in daily productivity due to differences in logging chance. It was assumed that all the machines would work 200 days per year. The effect of major delays, however, should not be overlooked. Yarding cranes, skyline machines, and helicopters are very expensive to purchase and, therefore, shutdowns will affect their average annual operating cost more than will shutdowns of the highlead machines.

TABLE 13. Yarding and loading costs: Phantom Creek

Machine type	Highlead plan Range \$/m ³	Skyline plan Range \$/m ³	Helicopter plan Range \$/m ³
Grapple	5.57	5.57	5.57
Highlead	9.57–20.07	9.75–20.25	9.48–19.99
Yarding-crane	9.62–11.83	9.97–12.18	—
Skyline	—	14.47–25.61	—
Helicopter	—	—	39.01
Average yarding	8.94–11.61	11.05–17.89	32.63–33.66
Realistic estimate	10.58	15.43	33.10
Road cost	7.02	5.27	0.50
Estimate roads & yarding	17.60	20.70	33.60

TABLE 14. Yarding and loading costs: Hangover Creek

Machine type	Highlead plan Range \$/m ³	Skyline plan Range \$/m ³	Helicopter plan Range \$/m ³
Grapple	5.57	5.57	5.57
Highlead	9.39–19.90	9.42–19.93	9.76–20.26
Yarding-crane	10.25–12.46	9.99–12.20	9.69–11.90
Skyline	—	14.32–25.45	—
Helicopter	—	—	39.01
Average yarding	8.92–15.91	11.16–18.56	24.70–25.92
Realistic estimate	12.90	15.53	25.31
Road cost	7.00	4.47	2.49
Estimate roads & yarding	19.90	20.00	27.80

The variations in productivity and the resulting ranges in cost reflect yarding distance, tree size, and terrain. The highlead has a large range because this system will operate under a variety of conditions, including strongly convex slopes. Under difficult conditions, the productivity falls but the machine will continue to operate. The yarding-crane, on the other hand, cannot operate when there is insufficient deflection, so costs are more uniform. Skyline systems are highly productive on well laid-out settings, but they are subject to serious operational delays. The time taken for changing yarding roads, rigging backspars, and securing tailholds can vary from hours to days. Experienced crews are essential to reduce these delays. Terrain features have little effect on helicopter or grapple yarding as the units operate only where they are effective.

The realistic estimated cost is a weighted average that takes logging difficulty and system used into consideration. The logging chance for each setting or cutting area in this study was assessed and the productivity estimated at good, moderate, or poor. The estimate was based on field data collected during the study period on other similar settings (Sauder and Wellburn 1987). Individual setting costs were calculated according to standard machine operating and ownership costs and the estimated productivity.

The total costs, including roads, show only a slight difference in the ranges for highlead to skyline. This is not surprising, because the skyline required less road, and a well-operated skyline will operate efficiently. On the other hand, skyline costs are less predictable than those for highlead, so there is more chance that a skyline will operate in the high-cost range. This is reflected in the realistic, estimated logging costs for Phantom Creek, where the skyline-logged timber would be inaccessible to the highlead. At Hangover Creek, all the timber accessible to the skyline would also be accessible to the highlead, so the reduction of high-cost roads required for the highlead would balance the higher cost of the skyline.

The helicopter costs would be higher for both areas, but particularly for Phantom Creek. A helicopter could log almost all the Phantom area, but this would not be accompanied by any less expensive conventional logging, which would bring the overall costs down.

4.7.2 Total logging costs

Table 15 shows the approximate value of the other costs that should be added to the road construction, yarding, and loading costs, to determine the total cost of the logs delivered to the Vancouver log market.

TABLE 15. Logging costs additional to road construction, yarding, and loading costs*

Logging phase	Range \$/m ³
Falling	3.00-4.00
Hauling	6.00-7.00
Road maintenance	1.00-1.50
Booming and sorting	4.00-5.00
Barging	7.00-8.00
Forestry	1.00-2.00
Crew services and administration	9.00-10.00
Total	31.00-37.50
Realistic estimate	33.00

* Source: Pers. comm. with industry managers, 1985.

Falling costs are affected by the size of the timber, the terrain, and the distance the fallers work from a road. Hauling costs are affected by the efficiency of loading, the hauling distance, and road conditions. Booming and sorting costs are affected by the number of sorts. Logs may be fully or partially sorted on the Queen Charlotte Islands or at destination after barging. Crew services include supervision and crew transportation. Administration includes accounting, management, insurance, taxes, and interest charges.

Stumpage charges payable to the provincial government were based on logging costs and log values during the study period. These charges are not included in Table 15. This report assumes that stumpage and profit would share the return from the difference between cost and value.

4.7.3 Log value, stumpage, and profit

Table 16 shows what the log values would have been during the study period. The total delivered value of logs from the Phantom Creek area decreased 30% from \$3.623 million in 1980, to \$2.535 million in 1984, and logs from the Hangover Creek area decreased 25% from \$10.752 million to \$8.102 million in the same period. Since that time, log prices have increased so that the 1988 value would have been higher than in 1980.

Table 17 shows what the total cost less stumpage and profit would have been for the years 1984 and 1988. In 1984, all operations would have lost money before payment of minimum stumpage. In 1988, because of an increase in log market prices, each operation, regardless of the machines used, would have paid stumpage and made a profit.

Tables 16 and 17 show that the log price is the major economic factor affecting logging on the Queen Charlotte Islands. All plans must be flexible enough to permit the forest companies to log the difficult high-cost areas when prices are up, and to let them move to the lower-cost areas when the prices are down.

TABLE 16. Log prices and values

Grade	Log prices (\$/m ³) ^a Cedar					Log prices (\$/m ³) Hemlock					Log prices (\$/m ³) Spruce					Log prices (\$/m ³) Yellow-cedar						
	%	1980	1982	1984	1986	%	1980	1982	1984	1986	%	1980	1982	1984	1986	%	1980	1982	1984	1986	1988	
F	2 ^b	80	64	111	100	159	0	0	0	0	0	12	180	149	115	154	2	255	128	181	191	345
H	25	59	53	94	64	91	24	77	53	48	50	75	25	70	55	57	74	25	127	85	138	157
I	18	55	43	89	59	73	20	72	51	46	48	65	14	63	51	51	49	18	81	51	74	85
J	44	38	38	81	55	54	45	66	49	29	36	40	38	37	31	30	30	44	40	37	34	59
X	11	0	0	10	8	17	11	35	26	19	30	24	11	29	25	20	26	11	0	0	9	8
Averages ^a		42.97	38.99	78.48	53.7	64.7		66.43	47.83	35.86	41.1	51.64	65.17	53.3	48.79	58.1	100.51	59.03	49.27	67.39	85.21	145.33
Vol-P	431						27 598						14 648					11 823				
Vol-H	17 265						76 637						54 210					20 088				

Sum
Phantom..... 54 500
Hangover 168 200

	Average by year (\$/m ³)				Total value by year (\$ thousands)			
	1980	1982	1984	1986	1980	1982	1984	1986
Phantom....	66.47	49.54	48.51	55.34	3 623	2 700	2 535	3 016
Hangover ...	63.93	48.86	48.17	53.14	10 752	8 218	8 102	8 938

^a Source: Truck Logger Magazines.

^b Source: FERIC cruise.

TABLE 17. Total cost, stumpage, and profit

	Alternative plan		
	Highlead \$/m ³	Skyline \$/m ³	Helicopter \$/m ³
Phantom Creek			
Road, yarding, and loading costs	17.60	20.70	33.60
Additional costs	33.00	33.00	33.00
Total delivered cost	50.60	53.70	66.60
Value of delivered logs 1984	46.51	46.51	46.51
Available for stumpage & profit (loss)	(4.09)	(7.19)	(20.09)
Value of delivered logs 1988	85.20	85.20	85.20
Available for stumpage and profit	34.60	31.50	18.60
Hangover Creek			
Roads, yarding, and loading costs	19.90	20.00	27.80
Additional costs	33.00	33.00	33.00
Total delivered cost	52.90	53.00	60.80
Value of delivered logs 1984	48.17	48.17	48.17
Available for stumpage & profit (loss)	(4.73)	(4.83)	(12.63)
Value of delivered logs 1988	79.92	79.92	79.92
Available for stumpage and profit	27.02	26.92	19.12

4.7.4 Planning costs

The intensive planning and detailed process for data collection outlined in this report are now in common use on the Queen Charlotte Islands. High-quality topographic maps are supplemented by field examination and terrain stability maps. Alternative logging plans are prepared and compared, rather than the first seemingly workable plan being selected. Cooperation with the agencies has improved so that information and advice is available when it is required.

The planning process requires an investment in capital for mapping and inventory, and an investment in manpower for field work and plan preparation. While the initial costs for mapping may appear high, the costs are minor when converted to a cost per cubic metre logged. For example, topographic mapping costs between \$1.90 and 2.15/ha, and terrain mapping costs between \$2.25 and 4.30/ha. Assuming an average volume of 400 m³/ha for the areas mapped, the overall cost of topographic and terrain mapping is between \$0.01 and 0.02/m³. Although ground-mapping the study areas is significantly more expensive than using aerial photographic methods, its cost of \$25.00/ha translates into only \$0.06/m³. Considering that roads are estimated to cost between \$5.00 and 7.00/m³ on the highlead and skyline-yarding plans, and that estimated yarding costs range between \$5.50 and 39.00/m³ for all plans, the costs associated with planning appear to be minimal. The lack of experienced layout people is probably a greater limiting factor.

The savings that can result from good planning include less road construction, easier road maintenance, increased yarding efficiency, and fewer delays, costs, and clean-ups resulting from mass wasting. These benefits far exceed the relatively small increase in planning costs necessary to achieve these results.

5 RECOMMENDATIONS

1. Planning must follow a logical process whereby specific problems are clearly identified; a problem analysis is undertaken to set objectives and goals; several solutions are developed; costs and environmental objectives are used to determine the best solution; the best solution is converted into action; and the plan is reviewed after execution. These planning steps should be followed when plans to log steep, unstable terrain are being developed.

Following a clearly identified planning process will help to:

- instill confidence and trust among individuals;
- identify clearly the type and quality of data required;
- establish a schedule acceptable to all parties for developing, submitting, and reviewing plans;
- provide clearly understood criteria for rejecting proposed development; and
- ensure there is full commitment to execute the plan.

Recommendation

For each proposed harvesting area, the phases of the planning process should be clearly identified, to ensure that responsibilities are assigned and sequences are followed.

2. A practical logging plan can be prepared only when sound data describing the terrain, soils, and forests are available.

The collection of detailed information should not only aid logging layout, but also provide data for comparing alternative plans. The experience of the field engineers who lay out the roads and the yarding settings, and the agency personnel who review the submitted plans, will determine the level and type of information required. Generally, the less familiar planners are with an area, the more assistance and data they will require.

Careful consideration must be given to the type and quantity of data that can be collected, to the most efficient way to collect it, and to how the data are to be analyzed.

Every effort should be made to use the data for other purposes as well (e.g., for stumpage appraisal), in order to reduce duplication of surveys and maximize the use of field personnel.

Recommendation

The type and amount of data collected for each proposed harvesting area should be agreed upon by the industry and agencies at the earliest possible stage in the planning process. The need for the data should be evaluated before field reconnaissance.

Then, mapping methods that provide more accurate representation of topographic features should be investigated.

Research should continue on how harvesting steep slopes affects site, terrain, and non-forest resources.

3. Good topographic and site stability information is required so that accurate logging plans can be prepared and their potential to meet environmental concerns can be assessed.

Recommendation

Topographic and terrain mapping must be undertaken at a scale that is compatible with operational planning, and at a standard that ensures there will be compatibility between maps. As a minimum standard, FERIC recommends a scale of 1:20 000 for development maps, and 1:5 000 for operability, stability, and layout maps. Field-layout personnel should use soil and vegetative characteristics to assess localized terrain stability, and should collect additional information when they are in the field.

4. Individual cutting permits and operability plans form part of an overall forest development plan. To minimize the length of road constructed and to improve the efficiency of logging, the planner must consider the timber adjacent to the proposed area and possibility of future access through it. The planner must know whether timber areas excluded from logging are temporarily deferred or permanently withdrawn. Temporarily excluded areas should be included in the long-term development plan.

Recommendation

Reasons for deferring or rejecting the logging of specific stands of timber should be carefully documented.

5. A full evaluation of the logging plans for the Hangover Creek and Phantom Creek areas could only be undertaken if the study areas are logged. However, the preparation of alternative logging plans demonstrated several points:

- The final plan was a compromise among several individual plans which all met various economic, engineering, and environmental objectives.
- Preparing at the outset specific plans that met the environmental and economic concerns allowed objective evaluation of the alternatives.
- The final plans were not necessarily operational and more field work would be required for implementation.
- Through the use of a variety of yarding methods, the potential to reduce soil disturbance and mass wasting is greater than occurs with plans that follow a single-system approach to development.
- Having a team of planners with different experiences and approaches was a significant factor in allowing the development of good alternative plans.
- The most feasible plans were those that matched road and yarding systems to the topography.

Recommendation

The preparation of alternative logging plans should be made before compromises are made.

6. No one harvesting plan is clearly superior to the others. In the study watersheds, the combined highlead-yarding plans would have the greatest proportion of their road lengths within sensitive terrain. However, the combined skyline plan would have a greater proportion of sensitive area disturbed by yarding. On the plan proposed for the Phantom study area, the total area of sensitive site disturbed by skyline yarding would be less than that for highlead yarding. However, a greater length of roads on the skyline plan would be on sensitive sites.

For the skyline settings, the choice of a suitable landing forced the road location into difficult construction areas, or good landings were simply not available. The road system for the mobile yarding crane would conform better to the natural topography. For all systems, the choice of road access up and along the steep slopes would restrict the location of most landings.

The helicopter offers potential to reduce logging disturbance to sensitive sites. However, there must be sufficient timber volumes and values to justify the costs. Plans for helicopter logging should be made in conjunction with the conventional logging plans for adjacent areas. This will enable the planner to eliminate difficult and expensive conventional yarding operations and their associated spur roads. This timber would then be left for the helicopter. A concern is that the reduced road access to upper portions of areas could increase tree-planting and forestry costs.

Recommendation

Harvesting plans must use a combination of logging systems that match terrain conditions to road corridors and landings. Alternative systems should be examined and initial incentives for their use provided.

7. The cost and economic analyses showed that fixed costs are affected in a narrow range by factors such as tree size, terrain, and logging system. Log values, which are determined by outside market forces, fluctuate over a wide range and have a major effect on the return available for stumpage and profit. During the study period, the value of the timber in the Phantom Creek area in 1984 was 30% below its 1980 level. The value increased again in 1988. Changes in log values can be sharp and unpredictable.

Recommendation

Logging planning on the Queen Charlotte Islands must be flexible enough so that difficult, high-cost areas can be logged when markets are high and lower-cost areas can be logged when prices are low.

6 CONCLUSION

The logging methods used by the forest industry on the Queen Charlotte Islands have changed during the past 8 years. Whereas highlead yarding systems were once the most common, mobile yarding cranes now dominate. Individuals responsible for planning have a better understanding of the consequences of disturbing steep slopes, and they are interested in logging these sites in an environmentally satisfactory manner. More information, such as stability mapping and landslide surveys, is available for planning. This information is more accurate than it was in earlier years, and is in a form that logging planners and managers can understand. This study, however, shows there is still a need to refine logging-equipment usage, to try different systems, and to ensure equipment is properly matched to the terrain.

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